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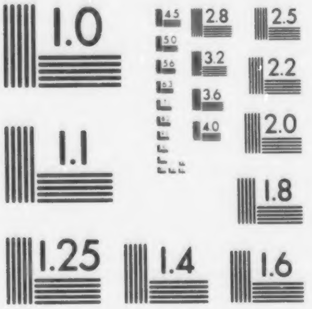

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COMPUTER ASSISTED INSTRUCTION IN SCHOOLS:
ACHIEVEMENTS, PRESENT DEVELOPMENTS
AND
PROJECTIONS FOR THE FUTURE

A Report Presented to Alberta Education

by

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with contributions by

M.A. Brebner and W.D. Winn

June 1980

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H.J. Hallworth

Ann Brebner

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CHAPTER 1

COMPUTER ASSISTED INSTRUCTION: AN INTRODUCTION

A Technological Revolution

This report is concerned with education: there is nothing unusual or startling about that. More specifically, however, it is concerned with a revolution which is taking place right now and which will have dramatic and far reaching effects on the direction and quality of education in the future. This is indeed both unusual and startling and, before the reader dismisses it as merely sensational writing such as can be read in the daily press, it is necessary to examine some of the facts.

Looking back into history only two other revolutions of comparable dimensions can be identified. The first of these was the introduction of the written word. Before this all instruction had, of course, taken place verbally. Although it is not known when written records were introduced, there were, as early as the fifth century B.C., objections that the use of written information made learning less stimulating and interesting, and unadaptive to individual student needs. In other words it was argued that it had a de-humanizing effect.

It was a long time before the second revolution took place, namely, the invention of printing in the fifteenth century. Again it met with some resistance and educators of the time expressed doubts about its value. They regretted the lessening of emphasis placed on the skills needed to produce the intricate hand written manuscripts. In France, the University of Paris went so far as to recommend that the art of printing should be suppressed. It is interesting to note how long it took for the benefits of this second revolution to reach education: it was not until the end of the eighteenth century that books were used extensively in schools.

The introduction of mass education in the nineteenth century was, of course, made possible by these two revolutions. Education could not be offered to everyone without their having reading and writing skills and without the use of printed materials. Such innovations from the past are the basis of our present educational system.

More recently, however, concerns have been raised about the size and structure of classes, in which one teacher lectures to a large group of students: all are assumed to be at the same level of achievement and to have the same abilities, and there is a consequent lack of individualization in learning. Much research has been done and much has been written on the topic. However, it has had little practical impact in the classrooms. For some students, the material presented is beyond their ability to comprehend, while others are not reaching their full potential.

It can be questioned whether the present educational methods have reached the limits of their capacity. Evidence suggests that, with an educational system based solely upon use of the methods derived from the two previous revolutions in the storage and dissemination of information, little further improvement in the effectiveness of the schools is possible, despite the best efforts of all professionals involved.

It is the third revolution, taking place at the present time, that can perhaps provide a solution to this problem. This is the technological revolution. Its effects on the manner in which information is stored and processed are dramatic.

Caught up in the midst of such a change it is impossible to predict its consequences. All the evidence indicates, however, that they will be even more far-reaching than those of the two earlier revolutions.

One thing is certain about the technological revolution: educators should not attempt to avoid it, to criticize it in ignorance, and hope that it will go away. It will not. They should grasp it and exploit it to its maximum potential to the end of improving the quality of education for everyone. Ways in which they might move at this particular point in time form the substance of this document.

Such suggestions are not easy to make. At the center of the revolution is the computer. Developments in this field have rapidly been gaining momentum recently and show no indications of stabilizing. A recent development is the microcomputer, a computer miniaturized to almost unbelievable proportions. It appears that it may well have an enormous part to play in improving education and individualizing learning.

In order to put all these assertions and predictions in their proper perspective, it is necessary to examine the progress of the technological revolution so far, and to see the uses to which some of the already existent technology has been put in the educational field.

The Development of Computers

Relatively computers are new: it is just 34 years ago that the first electronic computer ground out the results of its calculations. Yet the ever increasing impact they are having on our everyday lives, and the rapid developments still occurring in computer technology, make the term "computer revolution" not too strong a phrase to describe the situation.

The ENIAC, developed at the University of Pennsylvania between 1943 and 1946, weighed 30 tons and contained more than 18,000 vacuum tubes (Ralston and Meek, 1976). It generated a large amount of heat and could not operate for long periods of time due to the frequent need to replace some of the tubes. Like many of the early computers it was built to solve complex mathematical equations, usually with a military application. It is likely that the commonly held idea that computers are the province of mathematicians dates from this time.

The early development of digital computers can be conveniently categorized into successive generations. The first generation used vacuum tubes combined with various types of storage for the main memory system. These included mercury delay line storage, electrostatic storage, magnetic drums and, by 1953, magnetic core memory which is still widely used today.

Although when the transistor was invented in 1948 its advantages over vacuum tubes were recognized immediately, technological and production problems delayed its use in any quantity until 1959. That year marked the beginning of the second computer generation, all members of which contained transistors and magnetic core memory with, in some cases, magnetic drums, disks and tapes for auxiliary storage. This era was dominated by large scientific computers, especially the IBM 704 and IBM 709 series, totally unsuitable in all respects for most educational uses.

The third generation was characterized by integrated circuits and began in 1964 with the appearance of the IBM 360 series. This was the first time that a number of computers with a wide range of memory and circuit speeds were made into an upwards compatible series with the same instruction set by the use of micro-programming. Other features of the 360 series have become standards of the computer industry today. Among these are the use of eight-bit bytes to represent characters and the use of nine-track magnetic tapes.

UNIVAC's contribution to the third generation was the 1108, whose successor of the 1970's, the 1110, is used for computer assisted instruction (CAI) by the Chicago Board of Education.

The most spectacular growth area in the latter part of the third generation period was in the mini-computer field. The largest company in this field is Digital Equipment Corporation with its PDP series. The PDP-8's were first delivered in the mid 1960's and a newer, more powerful family, the PDP-11's, was introduced in 1970. These and other minicomputers, such as those manufactured by Hewlett Packard and Data General, comprise the hardware which has up to the present time been the most used in the field of education.

Beyond this point further generations have not been defined, not because technological advances have not been taking place, but because there have been rapid advances in the development of many of the components that make up a computer.

One very significant development has been the microprocessor, first introduced by INTEL in 1971. The impact of this is only just beginning to be felt, but it is through microprocessors that computers will reach the mass market. They are the basis of video games, and of the home computers now available for less than $1000 from a popular chain of stores.

Equally dramatic developments have been taking place during the 1970's in the field of computer memory, both in different types of main memory and auxiliary memory. The result is that, unlike many things, the cost of computers is constantly decreasing and will apparently continue to do so well into the future.

Herbert Grosch, past president of the Association for Computing Machinery, estimates that the computer revolution with known technology is now about two-thirds complete. He has predicted that by the year 2000 it will be possible to get 100 million components on one chip the size of a fingernail, and that machines with the power of the large systems available today, such as the CDC 6600, will by then be the size of a wrist-watch and cost something in the range of $10 to $100. Beyond this point it is suggested that the physical barriers presented by the speed of light and the atomic structure of metals will begin to have an effect.

It is obvious that for many years constantly improving computer hardware will be available at a constantly reducing cost.

Meanwhile, although the history of operational digital computers has been relatively short, the history of their use in education has been shorter still. In part this is due to the communications barrier which exists between a computer working in binary code and the human being thinking and communicating in natural language.

The early computers were usable only by those whose full time job was to build, program and operate such machines. However, by the mid 1950's the first high level languages had been developed. These made computers more accessible to professionals in other fields in that the user could communicate with the computer in more meaningful words and phrases.

The early languages which have had a significant effect on the development of computer software (Sammet, 1969; Sammet, 1972) include:

APT	1956	The first language for a specialized application area.
FORTRAN	1956	The first high level language to be widely used and still the major scientific language of today.
Flowmatic	1956	The first language suitable for business data processing.
COMIT	1957	The first string handling and pattern matching language.
IPL-V	1958	The first language for list processing.
COBOL	1960	A language for business applications and by far the most widely used language today.
ALGOL60	1960	A language used in Europe and by those concerned with theoretical aspects of programming.
LISP	1960	A list processing language which introduced the concepts of functional programming.
JOVIAL	1960	The first language in which a serious attempt was made to cover several areas such as scientific computation, input/output, logical manipulation and data storage and handling.
GPSS	1961	The first language to make simulation a practical tool.
JOSS	1964	The first interactive language.
FORMAC	1964	The first language to be used on a practical basis for mathematical problems needing formal algebraic manipulation.
APL	1967	A language with many higher-level operations which permit extremely short algorithms for the solution of many problems.

By 1973 there were more than 200 languages implemented and in use and in the intervening years over 40 more had lived and died. Of those in use, roughly half were languages for specialized application areas such as graphics, simulation, computer assisted instruction, machine tool control, and systems programming, while the remainder were divided among more general application areas.

This proliferation of languages has caused, and continues to cause, a major problem concerning the exchange of programs between different computer installations. In educational applications the problem is particularly acute and it is discussed in greater detail in another section of this document covering the area of languages for computer assisted instruction. It is to be hoped that the time has now passed when every computer scientist considered it a sign of respectability to have developed a new language.

The major general purpose languages in use today include COBOL, FORTRAN, BASIC, APL, SNOBOL, PL1 and ALGOL. BASIC is an easy to use on-line language derived from JOSS; SNOBOL is the string processing language in most general use; and PL1 is an extensive language containing many of the features from both FORTRAN and COBOL.

In terms of usage it is estimated that almost 90% of programs are in COBOL, 7% in FORTRAN, and 3% in BASIC, with the other languages accounting for the remaining fraction of a percentage. Although this is only an estimate it reflects the heavy usage of computers by the business community.

The Use of Computers in Learning and Instruction

Computers have permeated many areas of industry and business, from assisting with their own design and production to diverse functions such as the control of remote oil wells in the north and the calculation and recording of personal bank accounts. Their introduction in a variety of applications is continuing at an accelerating pace. In education their entry has been slower: this is a conservative field. However, it appears inevitable that in a short time they will have the same importance in education as in other areas.

The advent of high level languages enabled researchers in education to utilize computers. The first applications were mainly concerned with statistical analysis of data. Research on the use of the computer as a teaching machine began a few years later with initial work carried out at IBM's Watson Research Center, System Development Corporation, and the Universities of Illinois and Stanford.

Cooperation between IBM and Stanford University produced significant contributions in both the hardware and language areas of computer use in education. One result was the IBM 1500 system, the first and, to date, the only computer built specifically for educational applications. The language COURSEWRITER was also created and was the first special purpose language. Both these developments have had a great influence on research into computer assisted instruction and the IBM 1500 systems are only now being replaced by newer equipment. Also, probably more education programs exist in COURSEWRITER than in any other CAI language, although it is now dropping out of use.

The PLATO project at the University of Illinois started in 1960, and has had throughout the development of CAI a strong and innovative influence on all its facets including terminal development, time-sharing systems and an authoring language, TUTOR. PLATO today is still a very active and major project and will be discussed in greater detail later in this report.

All the early research centers necessarily carried out development work in time-sharing systems. The commerical introduction of such systems on mini-computers in 1968 reduced costs sufficiently for rapid developments to take place in a diversity of applications in many more research centers.

Time-sharing requires a complex operating system which allows more than one user to communicate with the computer at the same time, while giving each the impression of having sole use of the machine. The computer has sufficient speed to allow jobs for many users to operate on a modified round robin basis, returning to each one so fast that the user does not realize that many other jobs are being run at the same time. There are two large time-sharing systems in existence which have facilities for up to 1000 users, while the smaller minicomputers usually support up to about 64 users.

It is on time-sharing computers that most work on computer assisted instruction has been carried out to date. The hardware required for such a system includes a Central Processing Unit (CPU), main memory, auxiliary memory usually in the form of disks, and interfaces and terminals for the specified number of users. A very fast CPU is not normally required as a CAI application does not generate many numerical calculations; it does, however, need the ability to handle many terminals. The amount of main memory is dependent on the number of simultaneous users and the amount of auxiliary memory is usually fairly large as this is used to hold the programs. The system also needs an efficient time-sharing operating system and one or more high level languages with string and file handling capabilities.

On such computing systems educational applications are now many. Applications related to the narrower field of teaching and learning are numerous. It is not within the scope of this document, however, to consider all these, but rather to concentrate on computer assisted instruction.

Computer assisted instruction refers to the use of computers in an inter-active manner where the computer both presents material to and receives, analyzes, and acts upon responses from each student on an individual basis. In this way it can deliver complete courses, or units supplementary to classroom lessons. The former method is usually termed mainline instruction and the latter adjunct instruction.

The materials are often classified into tutorial, drill and practice, and simulation categories. In tutorial mode, information is presented, the student demonstrates understanding or need for further explanation, and the computer is highly responsive while at the same time advancing the goals established by the author of the curriculum.

In drill and practice a problem is printed, the student responds with an answer which is immediately marked, and the computer then gives either positive reinforcement or hints enabling correction. Further problems of similar type follow, often chosen randomly. A fixed number of problems may be given, or the process may continue until mastery is achieved, this being estimated by algorithms within the computer program. There may be emphasis on those problems with which the student is having trouble. A drill and practice program is often used as a test by suppressing the feedback.

In a simulation the student explores a situation which cannot be easily experienced directly for reasons such as time or cost, and learns by manipulating the interactions between the simulated events. For example, medical students may practice diagnosis and prescription on hypothetical computer simulated patients, and high school students may apply wild life management practices to herds of bison slaughtered in the 1800's.

Computer assisted instruction in this context does not include computer managed instruction (CMI), in which the computer is used to record the student's route and present position in a set of instructional modules. An exception may be made, however, where the management facilities refer the student, perhaps automatically, to selected material in CAI mode. Also excluded are those applications which are purely achievement or psychological testing, computer assisted counselling, administrative uses such as payroll, inventories and class scheduling, and computer science applications where the student writes and tests programs in a computer language.

CAI materials have been prepared and tested for many subject areas, from accounting to zoology, and from pre-school through to university and adult education. Research studies tend to show advantages for CAI in terms of shorter learning times and improved performance. These are particularly marked where the substance of instruction is suited to automated delivery and the objectives of the materials are clearly defined. It has also been highly successful where the student is particularly lacking in important skills and has little motivation to learn through more traditional means.

However, there is a very great difference between, on the one hand, a researcher carrying out an investigation of CAI in a small topic area with a manageable sample size over a period of days or weeks on a few terminals and, on the other hand, operational use of CAI integrated into the instructional setting of a school. In making an assessment of the potential of CAI in the public schools it is important to examine those projects, operating in schools, which are of relatively long standing. The more significant of these are therefore discussed in some detail. Projects covered are concerned with students in grades 1 to 12 and in special education classes, and those which, although not directly concerned with these groups, have generated materials suitable for their use. The projects discussed are in the United States, Europe and Canada.

CHAPTER 2

SOME CURRENT CAI PROJECTS OF MAJOR IMPORTANCE

PLATO

Description of the PLATO System

The PLATO project is located in the Computer-based Education Research Laboratory (CERL) at the University of Illinois, Urbana. It was among the first CAI projects when it was started in 1960 and has developed steadily since then, under the direction of Donald Bitzer, to be the largest and most influential project in existence today. Throughout its development it has contributed significantly to the leading edge of research in CAI in the hardware, software and courseware areas.

The project has received very large research grants. The original National Science Foundation grant of five million dollars was matched by the State of Illinois with an additional five million dollars. It has also received support from the Advanced Research Projects Administration and Control Data Corporation. In addition, other agencies have funded the development and operation of courseware in specific subject areas.

The purpose of the research has been to produce a cost-effective computer-based educational system with the power and flexibility necessary for provision of high quality interaction (Bitzer and Propst, 1977).

To achieve this, innovations in display technology, terminal design, communications hardware, system software, and courseware development have been needed.

The terminal is equipped with a plasma display panel, a flat 8-inch square transparent panel on which can be shown graphics and symbols as well as alphanumeric characters in many sizes and at any angle. The display is capable of animation and it also doubles as a projector screen for images stored on microfiche. This versatile panel was invented specifically for use with the PLATO system, and consists of a grid of 512 x 512 conductors at whose intersections a neon discharge can be ignited or extinguished under computer control. The writing speed for text is 180 characters per second and graphs are drawn at a rate of 60 connected points per second. The panel has a memory and does not require constant refreshing. Selective writing and erasing of parts of the display are possible without disturbing the remainder of the display.

The plasma panel is the main output device on the specially designed terminal. The principal input device is a keyboard which has a standard set of typewriter keys and an additional set of special keys, some performing a fixed action and others having different functions in different lessons.

The character generator includes 126 standard alphanumeric characters and 126 further symbols under author control. The latter, if needed, are loaded from the central computer and consist of special alphabets such as Greek for mathematics and science programs, or pictures used in some of the educational computation games at elementary school level.

To this basic PLATO terminal various peripheral devices can also be attached. The random access slide selector uses the plasma panel as the screen for rear projection of any one of 256 images from a 4-inch square microfiche. It is pneumatically driven under computer control. As the images are rear projected and do not interfere with the panel in any way, additional information can be presented simultaneously. The terminal can also be equipped with a touch sensitive device which covers the plasma panel and consists of a 16 x 16 grid of light emitting diodes. When intersecting light beams are interrupted by a finger, the position of this can be transmitted to the computer. Another device which can be attached to the terminal is a pneumatically driven random access audio disk. This allows rapid playback of pre-recorded messages stored on a 15-inch interchangable disk. Over 20 minutes of audio can be stored with an access time to any of 4000 starting points of about half a second.

A new terminal, the PLATO V terminal, is being developed and several of these are already in experimental use. This terminal is built round an IMSAI 8080 microcomputer and, because of the added intelligence, many functions previously performed by the main computer can now take place in the terminal itself.

If, as appears planned, this concept is developed further and first a stand-alone delivery system is built, followed by a system which allows both delivery and authoring facilities, then a very powerful cost effective CAI system will result.

At the present time, however, an unusually structured time-sharing system is used to support up to 1000 terminals, which can be attached either locally or over phone lines. The computer system consists of two linked computers, a CDC Cyber 73-24 and a CDC 6500, 2 million words of extended core storage and an extensive disk system containing programs and lesson materials. Programs and data are transferred from the disks to the extended core swapping memory and from here, when needed for execution, to the main memory. The very high transfer rate of the swapping memory enables the system to support such a large number of terminals with one eighth of a second response time.

The special communications hardware allows output from the computer to pass through an interface unit on to a standard television channel or microwave link, and then to site controllers each handling 32 terminals. From here the information is distributed to individual terminals over a 1200, 4800 or 9600 baud (i.e. bit-per-second) telephone line. Input from the terminals to the computer is over telephone lines. A line concentrator at the site controller multiplexes the information from the 32 terminals on to a single line and transmits it to the computer. This arrangement allows an average of 2.3 inputs per terminal per second, which is much higher than the actual number occurring during normal use.

A central philosophy within the PLATO system has been to encourage all instructors to develop some instructional material. This has resulted in thousands of completed programs being created by relatively inexperienced faculty members and student assistants. In order to achieve this an easy to use authoring language, TUTOR, was developed which minimizes the need for specialized knowledge of computer programming. It offers simplicity combined with efficiency and power. Particularly impressive are a natural language answer-judging capability and a series of instructions concerned with graphics design. Using TUTOR, lessons are written on-line from any terminal and their production and revision are greatly facilitated by a wide range of editing aids. However, it is estimated that inexperienced authors require an average of 237 hours to produce each hour of student material while the rate falls to an average of 26.4 hours for those with experience (Avner, 1978).

Users have access to between 5000 and 6000 hours of instructional material in over 140 subject areas. There are programs in engineering, pure science, social science, mathematics, foreign languages, business, medical and health sciences, and English. All modes of CAI are represented. Much of the material is tutorial, but there are also drill and practice programs and many simulations of biological, technological and social systems. There are also games, many of them instructional, which emphasize the philosophy that it should be fun to learn.

The materials have been used in schools, community colleges, universities, military training centers, correctional institutions and industrial sites. Three million contact hours of use on the system were logged between July 1974 and April 1977.

From this myriad of materials four topics will be discussed in greater detail, three because they pertain directly to school use and the fourth because it appears to be an imaginative use of the system and illustrates the power of CAI when it ceases merely to mimic traditional instruction.

Elementary Mathematics Project

The first of these is the Elementary Mathematics Project (Dugdale and Kibbey, 1977). Work started in 1972 and at the present time there are about 250 lessons covering the major areas. These are:

Whole number arithmetic, including

- meaning of operations
- computation techniques and practice
- algorithms
- place value
- renaming and symbols
- word problems

Fractions, mixed numbers and decimals, including

- meanings of fractions and mixed numbers
- equivalent fractions
- addition, subtraction and multiplication of fractions and mixed numbers
- meaning of decimal numbers

Graphs, functions and variables, including

- signed numbers
- variables and open sentences
- exponents
- graphing equations

During a three year trial period in cooperation with the public schools in Urbana and Champaign, the courseware was used by 700 fourth, fifth and sixth grade students in 18 different classes. In total this amounted to about 43000 hours of instruction. Each teacher had four terminals in the classroom and arranged a schedule for their use which allowed every student to use a terminal daily. Each student session was approximately 50 minutes in length, although the exact length was specified by the teacher. The teacher could also determine the sequence of lessons to be studied by an individual student, by a group within the class, or by the whole class. Alternatively, the teacher could arrange for the PLATO system to deliver an appropriate series of lessons. In this case a student session on the terminal started with a few minutes of drill and practice in basic number facts. Then the student chose a lesson from a list of several appropriate lessons and work on this material constituted the main part of the session. As the student mastered skills or concepts presented, new lessons appeared on the choice list and completed ones were taken off. Later in the session more general lessons or computational games would be added to the list.

In 1974-75 and again in 1975-76 data were also collected from about a dozen comparable classes not using the PLATO mathematics materials. Although analyses performed at CERL have been mainly oriented towards examining strengths and weaknesses in the curriculum, the data indicate that the daily use of PLATO materials can produce a positive effect on the student's achievement.

In the 1975-76 school year an evaluation was carried out by Educational Testing Service. The Level 2 (Form R) of the Comprehensive Test of Basic Skills (CTBS), a widely used standardized test, was administered at the beginning of the year and pairs of students were formed who were essentially identical in mathematics level. They were also matched by grade level and neighbourhood background. One of the pair worked on PLATO materials while the other did not, and the CTBS was administered again in the spring as a post-test measure. For 129 such pairs the mean gain in grade equivalent was 1.5 for those student receiving PLATO lessons and 1.2 for the control group.

In the following year, 1976-77, a similar evaluation using 128 matched pairs showed a gain in grade equivalent of 1.8 for the students using PLATO and a gain of 1.2 for the students not receiving PLATO lessons. In each case, these results were statistically significant at the 0.01 level. The higher gain by the experimental group in the latter year is attributed mainly to improvements in the courseware and in its organization and management.

As these results come from experiments of considerable size and scope they must be considered of prime importance in the evaluation of CAI. Each experiment involved over a hundred students and lasted for most of the school year. Moreover, they were carried out for successive years with the achievement of the experimental group increasing in the second year.

Students' attitude towards the PLATO mathematics materials was very positive, and their attitude towards mathematics itself, and towards their own ability to cope with mathematics, clearly improved with experience on PLATO as measured by a written questionnaire administered by Education Testing Service in 1974-75. Teachers' observations support these findings and access to PLATO is sometimes used as an incentive to improve behavior unrelated to PLATO or to mathematics.

That the materials teach successfully is of no surprise to anyone who has examined some of the programs. The philosophy that it should be fun to learn is well to the fore, with graphics and animation used frequently. For example, drill and practice in basic facts is represented as a road race. Each race consists of 10 problems with the student apparently racing another driver while in fact competing against the time taken on the previous attempt. In another ingenious educational game the student constructs expressions using three signed or unsigned numbers in such a way as to reach optimum positions on a special game board represented graphically. This requires the student to make several mental calculations before deciding on a final choice. In this game the opponent is PLATO!

The only criticism of the materials is that perhaps the graphics and animation are used a little too much. Sometimes there is so much material on the screen that the main concept being taught is rather obscured. However, there is no doubt that anyone implementing a CAI math project at a similar level should examine these materials in detail since they exhibit examples of excellent CAI techniques.

Reading Project

Another set of programs of interest is concerned with teaching reading at the grade one level (Obertino et al., 1977). This project was begun in 1971 supported by funds from the National Science Foundation. Over the course of the project approximately 200 lessons have been developed using touch sensitive animated displays; random access, computer controlled audio; and random access, computer controlled, colored microfiche. The lessons fall into the following categories:

Orientation
Date activities
Word detail
Memory skills
Letter names
Alphabet
Letter sounds
Blending
High frequency sight words
Enrichment sight words
Word meanings
Sentence building
Stories

Timed reading
Stories written by students
Games

These lessons have been used during the last four years to deliver an average of 15 minutes of instruction daily to more than 1500 students in nine public schools.

Lesson development has been guided by the philosophy that the student should control the terminal, rather than being restricted solely to responding to stimuli presented by it. The sequence of lessons, however, is prescribed by the teacher. For each student the teacher constructs three different lists: main activities consisting of the primary instruction, starting activities which are carried out at the beginning of each terminal session, and extra activities which are presented if the student completes all the main activities. A teacher typically spends about one hour per week prescribing lessons for a class.

An evaluation of this reading material revealed a small negative impact on student performance and consequently the materials will not be used further until they have been revised. No reasons are suggested by the project staff for this finding, but several points can be noted. First, the random access audio disk did not function reliably and, even when it did, the programming decision to halt a message immediately the student entered a response by touching the screen led to partial messages which often formed a garbled commentary. Secondly, it is doubtful whether first grade students either want, or are capable of, controlling their own programs. Thirdly, grade one may not be a suitable level for CAI of any kind since other studies have also failed to obtain any significant improvement in achievement when CAI is used to supplement instruction.

Use of the Elementary Level Materials in Special Education

Both the elementary mathematics and reading materials have been used successfully in the area of special education. The mathematics lessons have been used for two years with deaf students. There were no particular problems encountered in this implementation, except one concerned with the touch sensitive input. Normally, an indication is given that the input has been accepted by a "beep". This was not audible to the hearing impaired students and a small red light was installed to serve a similar function. When this was done the students used the terminals as eagerly and confidently as normal students. The instructors consider that, besides teaching mathematics, using the terminals has helped the students assume responsibility, make decisions, and learn to read (Dugdale and Vogel,1978).

The reading materials have been used, as yet on a relatively small scale, by very disturbed students in a special residential school. It appears that here too the use of the terminals has been successful in a large proportion of the cases both in teaching skills and, more particularly, in increasing attention span and concentration on the task.

The use of PLATO lessons with the handicapped is likely to be expanded in the future.

Science Programs

The PLATO computer system does not impose a pedagogical structure on the authors of CAI materials. An appreciation of the breadth of approaches used and of some creative ways of presenting material can be obtained from reviewing some of the chemistry programs. Although most of these are at university level the procedures and techniques are equally applicable in high school chemistry and physics. In all cases the material tends to be highly interactive, requiring frequent input in the form of answers to questions, predictions of outcomes of experiments, parameters to be used in simulated experiments, and interpretation of sets of data or facts (Smith and Sherwood, 1976). The duration of a lesson automatically adjusts to the student's needs.

Many of the programs could be described as controlled simulations. Much of science is based on the results of experiments and the importance of having students learn to design experiments and interpret experimental data is stressed. Simulated laboratory experiments are used either as a means of better preparing the students to carry out the actual experiment, or to help them develop important concepts from experiments which cannot be carried out in practice because of lack of adequate equipment, time or experimental technique. For example, in a simulated titration experiment, the student must specify all the steps, including controlling the flow from the buret, and then analyze the data. If he does not control the flow correctly in the animated diagram, disaster results and it is necessary to start over again.

It is also important for students to gain experience with problems for which there are many possible solutions. An example of this is the synthesis of organic compounds, in which there are many possible routes from the starting materials to the designated product. The student is given the starting material, and proceeds by suggesting a reagent for each step in the transformation. Since there are many possible paths the computer evaluates the end result of the reaction suggested and compares its structure with that of the desired material. If they are the same, the synthesis is judged complete; if not, the reagent for the next step is requested. This approach does not impose on the student a specific solution to the problem, but recognizes a wide range of acceptable routes.

These examples only serve to illustrate some of the features of this series of programs; also it is impossible to convey in words the dynamic nature of the animated, interactively changing displays. However, in actuality they represent the most effective use of a computer in teaching which has yet been devised.

Evaluation of the PLATO Project

The PLATO project staff have not carried out extensive evaluations of the overall effectiveness of their materials. Most analyses which have been done have been oriented towards determining strengths and weaknesses in the actual curriculum. Several of the former types of evaluation, however, have been carried out by Educational Testing Service, and the major one so far has been concerned with the use of PLATO programs in the community college (Murphy and Appel, 1978).

It commenced in 1972 when PLATO terminal laboratories were set up in five community colleges. At this time there was little appropriate instructional material in the five chosen subject areas, accounting, biology, chemistry, mathematics and English. It was hoped that by 1974 the college instructors would have learned the programming language TUTOR and developed their own courseware. This was not the case and additional staff were required for this task. One year was then spent getting the courseware into use and identifying those courses in which sizable numbers of students were using PLATO, as there was a wide variation in the amount of time spent both across the sections of a course and even across students in the same class. The total usage greatly exceeded the initial projections, but the amount of time spent by a student, originally projected as one-third of the instruction, was in practice less than this amount. From this phase it was concluded that a large system like PLATO, with terminals at varying distances from the central site, and users either studying different lessons or authoring materials, can work well as a medium for the delivery of interactive instructional materials.

As the courseware appeared satisfactory the second phase of the evaluation was initiated. This consisted of detailed examinations of student achievement, attrition rates, and attitudes using the measuring instruments and experimental design devised by Educational Testing Service. During the year 1975-76 data were collected in 162 classes. Based on the analyses of these data it was concluded that the use of PLATO lessons had no consistent effect on either achievement or attrition but that its impact on both student and instructor attitudes was favorable. It is the belief of the evaluators (Murphy and Appel, 1978) that the main reasons for this positive attitude were reliability of the system, a good active relationship with the CERL staff, interest and commitment of funds by the colleges' administration, and the control that the instructors had over the use of the system. A further indication of the success of the project is the continued usage of the system beyond the externally funded period.

Among the general conclusions which can be drawn from observing the PLATO project in operation, both in schools and at the central site, the one which stands out is that this is a very active project, strong in research and with creative CAI authors who are producing excellent courseware in many subject areas at all levels. An important aspect of this success is the philosophy that the teachers should be in control of the teaching materials, and that the materials should be presented in such a way that the students should find it fun to learn. This, combined with the fact that system crashes and malfunctioning terminals are rare, accounts for the very positive attitudes of all users of the system.

That authors have been able to produce imaginative courseware has been due in part to the plasma panel with the ability to control 512 x 512 points on the screen. With this resolution and the accompanying TUTOR software for graphics and animation, few programs have made use of the microfiche display facility. This may presage a general trend in CAI as cathode ray tube (CRT) screens become available with a similar resolution. However, need will remain for some computer controlled image display for showing coins, for example, in the teaching of money handling. PLATO's microfiche peripheral does not appear to be the most suitable, first because of the problems in producing the microfiche as opposed to slides, and secondly due to the need for compressed air to drive it.

The audio disk has not been sufficiently reliable in operation and research is at present being carried out in the area of synthetic speech. A VOTRAX voice synthesizer is in operation, complete with the necessary simple commands to drive it in the TUTOR language. Research is also in progress, although not so far advanced, with the COMPUTALKER voice synthesizer. It appears, therefore, that the PLATO project is definitely moving towards the use of synthetic speech and away from pre-recorded messages and their associated unreliable delivery apparatus.

Other less positive aspects of PLATO relate to funding. No CAI project will ever again receive such extensive research money for development of hardware, software and courseware. Consequently, some of the materials are well outside the price range of the average CAI project. PLATO terminals are expensive and when external funding ceases a school is unable to continue the use of PLATO from its own resources. TUTOR is an extensive language and at the present time requires a large computer system to support it. Also some of the courseware is more elaborate than it need be to present the concept being taught; the authors used the facilities simply because they were available. This also applies to the special keys on the terminal. A program may require the use of several such keys, consequently appropriate instructions must always be displayed on the screen. Similarly, there is sometimes a mixture of touch sensitive input and key input required in a program. This can become confusing for the students, particularly the handicapped.

Despite the costs, however, PLATO terminals are in use throughout the United States, attached remotely through telephone links to the central site at the University of Illinois. Apart from CAI, a special file structure allows the PLATO system to act as a form of electronic mail with many messages a day being delivered.

CDC PLATO

Apart from the system at the University of Illinois, there were in 1979 seven other PLATO systems in existence. All were built by Control Data Corporation (CDC) and result from a special agreement this computer manufacturer has with the University of Illinois. The system in Florida and that at the University of Delaware were purchased while the remaining five are owned by CDC. Two are in the main CDC offices in Minneapolis, one in the University of Quebec, one in South Africa and one in Europe. In 1980 an eighth system was purchased by the University of Alberta, and negotiations regarding a ninth system are taking place.

One of the configurations in Minneapolis serves approximately 40 CDC learning centers located throughout the United States and one in Toronto, Canada. Although the system is capable of supporting the plasma terminal, the one normally used consists of a CRT with the same resolution as the plasma terminal, namely 512 x 512 pixels, a keyboard, and a touch panel of clear plastic containing a grid of 16 x 16 wires. Optional devices which may be attached include a computer controlled slide projector and random access audio disk. Of particular interest is the fact that the touch panel is a standard feature of the terminal.

Some of the courseware developed at the University of Illinois is available on this system, and to this CDC have added several packages of their own. The emphasis in these has been placed on the education of adults and, in particular, on the training of personnel in business and industry. For example, American Airlines use PLATO simulations of cockpit instruments for training pilots, and several drug manufacturers use the system to give information about new products both to their sales representatives and to the hospital staff who will use them.

There is, however, one package which could be applicable to use in schools. It is concerned with basic skills and, although designed for the over 50 million adults who have less than a high school education, it could be used for remediation in the high school grades. It covers those skills in mathematics, reading, and language normally learned between grades 3 and 8 (Basic Skills Learning System - Curriculum Guide).

Each of the three topic areas is broken down into strands, which are major subsets of the topic with conceptual threads running through them. A strand is further subdivided into clusters, each of which is concerned with a basic concept defined by one or more specific learning objectives. Inter-related clusters are grouped into bundles.

For each cluster there is a pre-test, a tutorial lesson containing guided practice highlighting the key points of the lesson, drill and practice, and a mastery test.

Materials at the bundle level are designed to help retention of recently learned concepts. They consist of mixed drill and practice on all the clusters within the bundle, and retention tests which determine the need for review of any skills.

Individualization is carried out in several ways. First, when entering a strand, a student receives a diagnostic test. This begins with questions of the level of difficulty found at the mid-point of the strand and this level is adjusted according to the student's performance until the appropriate starting cluster is found. Secondly, on entering a cluster a student may choose to take the optional pre-test and if able to demonstrate mastery will move on to the next cluster. Thirdly, the bundle retention tests determine those skills, if any, which a student needs to review.

There are nine strands in the mathematics curriculum. These contain 74 clusters for which the average completion time is 133 hours. The strands are:

Basic number ideas
Addition
Subtraction
Multiplication
Division
Fractions
Decimals
Ratio, proportion and percent
Geometry and measurement

The reading curriculum contains 111 clusters organized into five strands. The average completion time for this entire curriculum is 207 hours. The strands covered are:

Making new words
Understanding new words
Understanding what you read
Thinking about what you read
Judging what you read

The average time taken to complete the language skills curriculum is 112 hours. There are 59 clusters in the five strands which are:

Language and usage
Building and using sentences
Word usage
Capital letters and punctuation
Writing letters

Between January and July 1978 several field tests were carried out on the basic skills package (Rizza and Walker-Hunter, 1978). Groups taking part in these tests included students from adult education centers, students in secondary school remedial programs, inmates of correctional institutions and hearing impaired students. All of the groups showed large gain scores after a relatively short time on the PLATO system. The gains were greater in mathematics than in reading, and in those studies where a control group was present most of the gains were statistically significant. The students' attitudes towards the materials and the PLATO system were very positive, and attendance was good with very small drop-out rates.

Based on the results of these field tests some modifications have been made to the courseware and further evaluation is being carried out. It appears, however, that this is already a good learning system and the only comprehensive one available for basic skills which has tutorial sections, as well as drill and practice material.

The PLATO system in Minneapolis also serves a project for gifted students in Houston. A terminal was successfully introduced into the program during the 1977-78 school year. The students mainly used it in author mode to produce tutorial and simulation programs and found this both interesting and challenging. An expansion of this project is planned and it is hoped to have four terminals in operation.

The school district also intends to use the terminals for other purposes. Among these is the teaching of courses such as the Persian and Russian languages for which there is a small demand, insufficient to warrant the hiring of teachers. It is also planned to develop courseware to help teachers improve their job skills, a sensitive topic on which they do not appreciate instruction from their colleagues.

Of the other PLATO systems, both the Florida system and the one in Delaware are relatively new, but appear to be making a significant impact both in their host universities and in educational institutions in their vicinity.

At Florida State University, Tallahassee, the Computing Center is cooperating with CDC to field test the remedial mathematics lessons of the basic skills package. For this purpose eight terminals have been installed in each of three high schools and will be used to test the effectiveness of the materials for remediation for those students who have failed the mathematics portions of the Florida eleventh grade tests.

Departments at Florida State University planning to make use of the system include Library Science, Psychology, English, Classics and Philosophy.

At the University of Florida, PLATO lessons are used in the School of Pharmacy, the Institute of Food and Agricultural Science, the Law School and the College of Education. The latter offers a graduate course on the use of PLATO in computer assisted instruction and provides the students with "hands-on" experience in designing and implementing PLATO lessons.

Two junior colleges have access to the system. Florida Junior College uses four terminals in conjunction with courses in mathematical statistics, microbiology, economics, anatomy and physiology. Palm Beach Junior College has three terminals in continual use and expects to increase this number to four. Here PLATO lessons are used in teaching physics, genetics, biology and data processing.

The PLATO system at the University of Delaware was installed in March 1978. It originally supported approximately 60 terminals and its capabilities were expanded early in 1979. Although not directly related to use in schools there are two points of interest about this project. First, it appears to have been very readily accepted by the teaching staff and more than 100 faculty are actively involved in courseware development in 29 academic areas. A programming specialist is assigned to each academic area participating in the PLATO activities. Secondly, the PLATO system is not only being used for mathematics and science instruction, but has been introduced successfully in courses not normally associated with CAI, such as art, home economics, physical education and even music and drama! There are many ideas here which could be adapted to the school curriculum.

The University of Quebec fulfills a role in Quebec similar to that of the University of Athabasca in Alberta and has students throughout the Province. It is engaged in translating PLATO materials into French.

Up to the present time the PLATO system has always been based upon a large computer system. The costs of such a system, together with the royalty costs of CDC software and courseware, are considered to be prohibitive for its use for CAI in schools. At the present time the value of PLATO lies in the ideas contained in its excellent courseware.

Microprocessors, however, are already in use in the PLATO V terminal, with some down-loading of program material done by the main computer. Indications are that, at the University of Illinois PLATO project at least, this trend will continue and there will be a gradual movement away from the concept of a large central system. A stand-alone microcomputer system, using a CAI language similar to a subset of TUTOR, is already marketed by Regency-Carroll of Champaign, Illinois. It appears, therefore, that in the near future other much less expensive hardware may be used to suport the PLATO system. If this occurs it would certainly have a very great impact on the whole field of CAI as the system undoubtedly has the best available courseware and the facilities to develop much more, important factors towards which the emphasis will tend to shift in the future.

Stanford University

Another project, which was among the first in the field of CAI and has had a strong and continuing influence on its development, is that at Stanford University. This project was established in the Institute for Mathematical Studies in the Social Sciences under the direction of Patrick Suppes in 1963. As in the case of the PLATO project this was before time-sharing systems were available commercially, and it was therefore necessary for Stanford to become involved both with the development of time-sharing systems and languages. There are, however, very few similarities between the two projects as Stanford has not been much concerned with hardware development, and the underlying philosophies are very different and have consequently caused developments in entirely different directions.

In its early years the project received large research grants from the Carnegie Foundation, the National Science Foundation and the U.S. Office of Education. Again, as in the case of PLATO it is unlikely that funds of this magnitude will ever again be available for CAI.

The initial hardware consisted to two computers, a Digital Equipment Corporation PDP-1 and an IBM 1800. For each of these a time-sharing operating system was first written and then CAI programs were implemented in the basic machine code of the computer.

This work on the IBM 1800 system was partly instrumental in the production by IBM of the 1500 system, the only computer system ever designed specifically for CAI applications.

Stanford also cooperated with IBM in the development of the authoring language COURSEWRITER which was available on the 1500 system and later on other machines, mainly those manufactured by IBM.

Most of the courseware produced has been in the area of drill and practice, with few tutorial programs or simulations. A concentrated effort was made to cover the curriculum in mathematics, reading and language at the elementary school level.

The first programs were in the field of elementary mathematical logic and consisted simply of two lessons which were used in the laboratory by a small number of grade 6 students in 1963.

In 1964-65 the project was expanded with 40 grade 4 students getting daily drill and practice CAI on a computer controlled typewriter in their school. This was the first instance in which a terminal was used remotely through the ordinary telephone network. In order to do this Stanford cooperated with a local manufacturer to produce an acoustic coupler.

From this point, extensive series of drill and practice programs were built up for grades 1 to 6, with an increasing number of students using them each year.

In 1968 Stanford acquired another computer, a Digital Equipment Corporation PDP-10, a medium to large sized computer capable of supporting 64 terminals, and at the time probably the most efficient and reliable time-sharing system available.

In this same year the drill and practice programs were used by 4000 students in California, Iowa, Kentucky and Mississippi, using terminals over telephone links and making use of the time zones to accommodate the large number of students on the computer systems.

The mathematics programs were based on Suppes' book Sets and Numbers and a California state text. Students worked on the programs for a particular topic two to four weeks after it was introduced in the classroom.

The programs were systematically built. Each grade level was divided into 24 concept blocks or units. Each block was subdivided into 7 lessons, each of 5 to 10 minutes duration. The first lesson was a pre-test and the student's performance on it determined the difficulty level of the lesson for the next day. If the score was between 60% and 79% the lesson was of the same difficulty; if it was above 79% the student moved up one level; and if it was below 60% the student moved down one level. In all there were five different levels at which the students were working after two days on a block, a simple but effective technique for individualizing the lesson materials.

The final lesson in the block was a post-test, after which a student moved on to the next block in the linear sequence of 24 blocks. Periodically review tests were presented which covered the material in the blocks already completed.

Within a lesson, if the student gave the correct answer to an item, the next item was printed. A first incorrect answer to a problem caused the word "wrong" to be printed and the question to be repeated, a second error produced "wrong" and the correct answer, while for a third error the correct answer appeared followed by the next item. Each question was timed, with a maximum of 10 seconds being allowed as "thinking" time. If this elapsed the phrase "time up" was substituted for "wrong".

The attitudes of students, teachers and parents to this mode of instruction were very positive (Suppes, Jerman and Brian, 1968).

Extensive research on the effect of the use of this daily drill and practice CAI was carried out between 1966 and 1968. In these studies students in the experimental groups received 5 to 8 minutes of CAI daily while the students in the control groups received only classroom instruction. The arithmetic portion of the Stanford Achievement Test was used as the pre-test and post-test throughout to measure changes in achievement levels.

In the first year 800 students in California in grades 3 to 6 were involved in the comparisons. The results showed that those using CAI gained more at all grade levels except grade 5. The greatest difference in gains occurred at grade 4. The CAI groups moved from an initial mean grade level of 3.7 to 5.4 on the post-test, a gain of 1.7 grade levels. The control groups' mean was 3.8 on the pre-test and 4.8 on the post-test.

In the next year the evaluations were expanded to include 1000 students in California and 600 in Mississippi, and covered grades 1 to 6. Of the 41 comparisons carried out, 29 favored CAI. When subdivided into topic areas, 16 out of 18 comparisons on computation favored CAI, while on concepts the figures were 7 out of 14, and on applications 6 out of 9. The largest gains were at grade 3 where the Californian students gained an average 2.28 grade levels and those in Mississippi 2.03 grade levels in one year. Of the total 41 groups, 31 of those using CAI gained more than one grade level during the year.

Perhaps the most significant fact to emerge from this research, however, is that the low ability students gained relatively more than the middle and high ability students.

Later the curriculum was changed from the concept block structure to a strand structure. This was done by a team of curriculum specialists and programmers and provided a much more flexible system, not confined by grade limitations and hence resulting in more sensitivity to the students' needs and more individualization in the materials they received. There were 14 strands in the elementary mathematics curriculum, from counting to problem solving. Each strand was a systematic arrangement of progressively more difficult content. Students moved through these materials according to their abilities in each topic and could be working at widely differing levels on the different strands.

This curriculum formed the basis for that presently marketed by the Computer Curriculum Corporation.

Later developments at Stanford have concentrated more on curricula for university level courses, and have covered such areas as foreign languages (particularly Slavic languages), logic, and computer languages. The only relevant point in this work is the assumption that CAI provides a means of teaching a small enrollment course which would otherwise not be taught, either due to lack of staff or because offering such a course in the conventional manner would incur too high a cost.

Computer Curriculum Corporation

The Computer Curriculum Corporation (CCC) was formed in 1969 by Suppes as a commercial outlet for the elementary school curriculum materials in drill and practice developed at Stanford University. Although the materials have been further developed since that time, they still bear a strong resemblance to those produced at Stanford in the 1960's. CCC's courses follow a drill and practice format, and most of them, including the mathematics, reading, and language courses, have a strand structure. A strand represents one content area of the curriculum, for example division, and consists of a string of related items whose difficulty progresses from easy to hard. One significant difference between CCC's approach and Stanford's is in the mathematics curriculum. Originally the items in the strands consisted of a fixed number of fixed problems, whereas now the items are generated randomly from parametric descriptions of the required difficulty. One result is that considerably less computer storage space is required.

Evenly spaced points on a strand are marked as corresponding to school grade levels and, within each grade level, there are further points which represent each tenth of the year. These are used to indicate each student's position on each strand in the reports for the teacher.

A lesson consists of a mixture of exercises from the different strands. There are various ways in which this could be done. The number of items from each strand could be chosen randomly, or an algorithm could be used which matched the proportion of items given from each strand to that found in the average text book, or a more individualized procedure could be used where more items were given from those strands in which the student had lower placements. The full details of the algorithms used by CCC to generate a lesson are not available.

When starting a course, the first ten lessons are used to place the student at the correct point in each strand. During these ten lessons, movements of half a grade are made until the student's working level in a strand is reached. From this point on, as the lessons are presented, the student's record in a strand is compared with preset performance criteria and it is determined whether more practice at the same level should be given, or whether the student should be moved back along the strand to easier items for remedial work, or moved ahead. Again the details of how these decisions are made are not disclosed.

A record keeping program is associated with each course and monitors the students' positions and performance in each strand separately.

Three types of reports are available for the teacher: the course report, the grouping report, and the gains report.

The course report first gives, for each student in the class, the name, ID, number of lessons received and total time spent on the course to date. This is followed by details of the last session and shows the number of items attempted, the number correctly answered, and the number on which time ran out before an answer was given. Next, for each strand the grade level as a decimal number is given, and this is followed by the overall average grade level.

The grouping report follows the same format as the course report and is identical to it in all areas, except that giving the grade levels in each strand. Here it shows only the grade level in that strand in which the student has his lowest achievement level and, in addition, the grade level in any strand in which he is a third of a year or more below his average grade level. This report identifies students' weaknesses in order that remedial lessons may be given.

The final report, the gains report, can be obtained on a monthly basis. It gives, in addition to the name and ID, the monthly gain in a fraction of a grade level and the total gain since starting the course for each student in the class. Also printed out are the time spent on the course during the month and the total time spent to date. The report gives the teacher a longitudinal view of each student's progress.

At present sixteen courses are available. These are as follows:

1. Mathematics for grades 1 to 6.

   This course covers grade levels 1.0 to 7.9 in 14 different strands.

2. Reading for grades 3 to 6.

   This covers grade levels 2.5 to 6.9 in 5 strands.

3. Reading comprehension for grades 3 to 6.
4. Language arts for grades 3 to 6.
5. Language arts topics for grades 3 to 6.

   This covers the same curriculum as the language arts course with strand structure, but the material is arranged in topics. Within each topic are between five and eight lessons from which the teacher can select a sequence.

6. Problem solving for grades 3 to 6.

   This course gives practice in solving word problems.

7. Mathematics for grades 7 and 8.

   This course is arranged in nine strands, and an additional five optional strands, which may be selected by the teacher or student.

8. Reading for grades 7 and 8.
9. Adult arithmetic skills
10. Adult reading skills
11. Adult language skills I
12. Adult language skills II
13. GED preparation course.

    This consists of five sections, one for each test in the examination.

14. Fundamentals of English
15. Introduction to algebra
16. Spanish reading

As in the case of PLATO systems available from CDC, it is necessary to purchase a complete system, including special hardware and software, in order to run any of these courses. The present system is the CCC-17.

The computer at the center of the system is from the Data General Nova Series, a fairly inexpensive line of mini-computers. It does, however, have some modifications, specified by CCC, built into it at the time of manufacture. To this computer very simple CRT terminals built by CCC are attached. The maximum number of these which can be supported on one system is 96. The terminals are attached through cluster controllers, again made by CCC, each of which controls 16 terminals.

On this hardware configuration the courseware is implemented in machine code.

There are several advantages and disadvantages with a CAI system constructed in this way. The advantages are that machine code makes the most efficient use of the hardware in respect to both storage requirements and speed of execution.

These are, however, more than offset by the disadvantages inherent in such a system. In particular, there are problems in effecting changes to the courseware. Changes to machine code programs can only be made by experienced programmers and even for them such tasks are very time consuming. It would not be possible for teachers to adapt any courseware written in machine code to their needs.

Hence in the CCC courses teachers could not change the content of a course, the order of presentation of the sections, or any of the algorithms which control the presentation of the course.

The only parameters for which a mechanism exists to make changes are the session time, the time allowed for a student to enter an answer, and the time the question remains on the screen after it has been marked.

Given the drill and practice format of the courseware and the inability to modify it, the situation could arise in practice where the system was actually dictating what should be taught and in what sequence. It is considered that a CAI system should not do this; it should be under the control of the teacher.

There are, however, developments taking place some of which may ease the rigidity of the system. One is the announcement of a BASIC language, and a second is a facility to enable the system to be connected into a computer network. Other developments which will improve the quality of the present "text-locked" courseware include a color graphics terminal and a speech output device.

In spite of the shortcomings of its system, CCC has provided the major portion of all CAI which has been used in schools on a regular basis. The corporation has been expanding rapidly over the past few years and has installations in many parts of the United States. All are to be found, however, in areas where money is provided from federal funds for the education of the disadvantaged. This invariably means that CAI has been used with students who are black, or of Mexican or Puerto Rican descent.

One-third of the installations are in Texas, where the organization of the school districts is convenient for bringing the systems into use. The state is divided into 20 regions, each of which has a Service Center which handles, among other things, a large media library. Five of the regions have CCC systems, with the computer in the Service Center and the terminals distributed amongst the schools. The Houston region, for example, has 500 terminals utilized in this manner.

Other systems are in California, Seattle, Mississippi, New York, Illinois, New Mexico, Kansas, Pennsylvania and Arizona.

In many of these settings the mathematics, reading, and language courseware has been evaluated either by CCC or by the local school boards (Macken and Suppes, 1976; Poulsen and Macken, 1978). All the evaluations show favorable results from the use of the CAI drill and practice programs and in some studies dramatic gains in achievement are reported. Evidence is reported which supports the recommendation that each student should complete a ten minute lesson daily for each course being taken.

Two very different implementations of the CCC materials are those in Chicago and Los Nietos. In Chicago the materials have been in use over a long period of time with a very large number of mainly black students and are running on a large computer. In contrast, the Los Nietos project is both newer and smaller, utilizes the complete package of hardware, software and courseware supplied by CCC, and gives CAI to students mainly of Mexican origin.

Chicago

Description of the System

In Chicago CAI in the form of drill and practice has been used on a large scale since 1971. In that year seven schools, each with 15 terminals, participated in the CAI activities. During the 1977-78 school year 59 schools were involved. Of these, 54 were elementary schools, while the remaining five were concerned with the education of the physically handicapped.

The project is federally funded in that it is one of about a dozen projects offered by the Public School Board for those schools in low economic areas where academic achievement is below average. These schools receive "poverty" money directly from the federal government and with this "buy" special projects from the School Board. It is therefore not an option available to all the Chicago schools, and not all schools which could obtain CAI do so.

The computer system now in use is a UNIVAC 1110 located in the central office. To the system are attached three disk drives, seven drums which contain the operating system and the curriculum, four tape units, two line-printers, and a card reader. The system supports 921 terminals, in clusters, through 64 ports operating at 4800 baud.

Each school which "buys" CAI receives a group of 15 CRT terminals and one line-printer. At the present time all the CRT terminals are identical, which provides for efficient maintenance. The CRT screen has 12 lines of 80 characters, and there are options which allow for lower case letters and cursor control necessary for long division examples. These terminals were first produced by UNIVAC in 1971 and, at approximately $4,300 each, are now expensive for the facilities they provide. In the near future it is planned to have a mix of terminals on the system in order to make graphics available for the handicapped students. The line-printer is used to supply daily reports of student progress to the classroom teachers. It is operated by an aide whose salary is also supplied, as part of the package, by the central office.

All the equipment was purchased at a price of approximately six and one-half million dollars.

The courseware which is used is basically the Computer Curriculum Corporation materials in mathematics, reading and language arts. However, the Chicago School Board was among the first to purchase these and their agreement with CCC is such that they may alter the supplied curriculum. The manner in which the materials are implemented on the UNIVAC 1110 makes modification a relatively simple matter and changes have been made to tie the CAI more closely to the curriculum taught in the classroom. As the CAI materials are totally drill and practice in nature, this ability to be able to modify them appears to be a very necessary feature.

In the same way as all schools are not eligible for CAI, so also within a school not all students are eligible. The conditions of the funding are such that only those students one and a half years or more below their grade level in reading achievement may participate. These students receive ten minutes drill and practice in reading and ten minutes in one of the other two areas every day. The daily practice is considered important, as also is the need for the student to work independently and successfully as an individual.

Reading Program

The reading program consists of six strands and is available for levels 2.5 through 6.9 (Cooney, Litman and Zerlentes). The six strands are:

	Levels
Basic sentences	2.5 - 3.4
Word attack	3.5 - 6.9
Vocabulary	3.5 - 6.9
Literal comprehension	3.5 - 6.9
Interpretive comprehension	4.0 - 6.9
Work-study skills	3.5 - 6.9

In each CAI reading session given at a terminal, items from all the strands active at the student's average achievement level, are presented. For example, a student whose average achievement level is 4.7 receives items from five strands, whereas a student at the 3.8 level receives items from the second, third, fourth and sixth strands only. As a student responds, the accuracy of the answers is evaluated and the level of items presented is adjusted accordingly. Such movements in each strand are independent of ability and progress in other strands. The program allocates a specific portion of the session time for each active strand according to the average achievement level of the student, and does not specifically concentrate on those strands in which the student is at lower levels.

All the items in the reading program are divided into classes, each consisting of five items of similar type and difficulty. Progress depends upon success within each class. If all five items are answered correctly, the student moves to the next class. If one is incorrect, the student still progresses but the incorrect item is added to the next class, making a total of six. Missing two or three items means remaining in the same class, while the student who gets four or five incorrect moves downward to the previous class. These criteria apply to the entire reading program.

Mathematics Program

The CAI mathematics program is available for achievement levels 1.0 through 7.9. It consists of 14 strands and emphasizes all the computational skills of elementary mathematics except geometry. It differs from the reading program in that the strands begin and end at a variety of achievement levels, and in that the actual problems are not stored, only the algorithms to generate them using random numbers.

The 14 strands are:

	Levels
Number concepts	1.0 - 7.9
Horizontal addition	1.0 - 4.4
Horizontal subtraction	1.0 - 4.4
Vertical addition	1.0 - 5.8
Vertical subtraction	1.6 - 5.8
Equations	1.5 - 7.9
Measurement	1.6 - 7.8
Horizontal multiplication	2.6 - 5.8
Laws of arithmetic	3.0 - 6.8
Vertical multiplication	3.5 - 7.8
Division	3.5 - 7.8
Fractions	4.0 - 7.9
Decimals	4.0 - 7.9
Negative numbers	6.0 - 7.9

A student's average achievement level determines both the strands from which problems will be presented and also the proportion of problems from the different active strands. The student's movement in each strand is determined by the performance on a given number of problems. For example, at the 5.0 level in the division strand, 12 out of 13 problems must be correctly answered before the student is moved forward, while a score of 4 or less will cause the student to be moved down a level. Failure to solve the first 3 problems causes the student to be lowered one achievement level to avoid continuing failure. As both the strand and the problem parameters are chosen randomly, the student does not receive problems from one strand consecutively.

Language Arts Program

The language arts program emphasizes syntax and the mechanics of the English language. It consists of two parts, a strand section structured in a somewhat similar manner to the reading and mathematics programs, and a part called TOPICS which is only presented at the specific request of the teacher.

There are eight strands as follows:

	Levels
Principal parts	3.0 - 6.9
Verb usage	3.0 - 6.9
Subject-verb agreement	3.0 - 6.9
Pronoun usage	3.0 - 6.9
Contractions, possessives and negatives	3.0 - 6.9
Modifiers	4.0 - 6.9
Sentence structure	3.5 - 6.9
Mechanics	3.0 - 6.9

Each student receives an equal number of items from each active strand during a session at the terminal. A strand is divided into classes, each representing one level of achievement. A class contains 60 items, all of equal difficulty and grouped as six sets of ten items. Every time a student completes a set an evaluation is made and, dependent on the result, the student either moves up to the next achievement level, or proceeds to the next set in the same class, or moves to a lower class.

If the teacher has requested the TOPICS option, then a lesson on one of these will precede the materials from the strands for each student in the class. There are 80 topics in total, from which a teacher can choose up to maximum of 20 for the class. Each topic contains from five to eight lessons and each student in the class must be working on the same topic, although not necessarily on the same lesson. However, topic lessons are individualized in the sense that they have two reading levels, and the ratio of high reading level items is determined for each student by performance on the previous lesson.

Reports

For each subject area two types of achievement reports concerning student progress are available. These are the Daily Class report and the Periodic Gain report. Both are obtained by the aide using the line-printer, the former daily and the latter at the end of each month.

The Daily Class report lists, for each student, ID, name, average achievement level, number of sessions, percentage correct at last session, and the current achievement level for each of the active strands. This is followed by a summary indicating the highest, lowest, and average achievement level in each strand.

The Periodic Gain report consists of a four line summary for each student, and indicates the number of sessions completed and number of months since base data were established. This is followed by the base data date and achievement level in each strand, the current data in a similar format, and the gains. The base data is calculated during the student's first ten sessions.

In these sessions, following initial placement by the teacher at the average achievement level, the computer presents materials from the strands at this level. If the student does well in a particular strand, the level is raised by half a level; if he does poorly, it is lowered by the same amount; otherwise the level is not adjusted.

Evaluation of the Project

The project is evaluated every year, usually by comparing it with other similar special projects offered by the School Board. In the report for 1975-76, for example, the CAI project was compared with four others which also emphasized individualized diagnostic and prescriptive procedures (Clendenon).

The first of these was Programmed Reading, where the teacher guides the student through programmed work books supplemented by some audio-visual materials. The second project was Prescription Learning, in which each student works from a prescription produced from a computerized diagnosis of a placement test. The prescription lists sources of study and practice work for each skill weakness diagnosed, and progress through these materials is guided by a teacher. The third project, known as System 80's

Program, employs teaching machines with both audio and visual components. Student response is by means of one of a set of multiple choice keys. The lesson sequence is prescribed individually on the basis of machine-administered criterion-referenced tests. The final project in the evaluation was the High Intensity Center, which is a laboratory equipped with a large assortment of well-ordered and organized materials to comprise an instructional management system by means of which the teacher can diagnose skill weaknesses and prescribe sequenced lessons to overcome them.

The conclusions of the evaluation were that there were no important differences in the students' attention to task and attitude towards the activities. Further, none of the five activities could be reliably ranked as more effective than the others in promoting reading achievement. However, computer assisted instruction had a cost effectiveness ratio large enough to be a deciding factor in purchasing this activity instead of one of the others. Also, it was considered capable of serving even larger numbers of students at relatively small increments of cost. Finally, in favor of CAI, mean gains in achievement appeared to be better retained across age groups than in the other activities.

When the Chicago Board of Education was carrying out a feasibility study in 1969, several other large U.S. cities were also contemplating setting up CAI projects. Among these were New York, Philadelphia, Detroit and Memphis. Only Memphis, with two saturated Hewlett Packard machines, has any CAI at the present time.

New York leased hardware and now has no funds; Detroit was doing its own development and as yet has nothing in operation. What factors, then, have contributed to the success of the Chicago project? One is undoubtedly that it started at a time when it was possible to obtain the CCC materials together with the agreement to be able to alter them. The Chicago School Board would have liked to produce its own materials but realized the size of this task was too great, both in time and manpower.

Another important factor concerns the relationship between the project staff and the participating schools. To maintain an effective relationship the central office staff not only run inservice training courses which highlight the value of CAI as a teaching tool, but also spend about half their time out in the schools.

Maintenance is also carried out very efficiently, facilitated by the use of one manufacturer's equipment and a single terminal type.

However, while it is obvious that CAI in its drill and practice mode has been effective in upgrading students' skills in reading, mathematics and language arts for large numbers of students (more than 10,000 in 1975-76), over a period of seven years, it appears that the project is totally operational in type and that it has no developmental future. This is unfortunate, since large quantities of data could be collected to evaluate and improve the materials. It was observed that some language examples, although grammatically correct, were stilted and not part of normal English usage. Also, the programs could be still more useful if they were adaptive and responsive to the individual user at the specific question level. Students who were observed entering the wrong answer to a question, from a choice of two, often simply entered the second answer and made no attempt to understand the example. Consequently a similar problem caused the same difficulties later. A small remedial teaching sequence would have corrected this immediately.

A final critical point concerns the printed reports from the computer. To see where students are having problems the teacher needs to use the report in conjunction with the teachers' guide for CAI. It would be useful for a busy teacher if all the necessary information was contained in the printout.

Los Nietos

The Los Nietos School District, in the Los Angeles area, has been using computer assisted instruction in relation to a program for basic skills at the elementary level since the 1974-75 school year. The project was made possible by federal funding supplied for the education of disadvantaged students. About 80% of the school population is from minority groups.

An IBM 370/115 computer dedicated to CAI was installed during the first year. It initially supported seventeen 2741 typewriter terminals but this number was increased to 24 before the end of the year. The language available on the system was COURSEWRITER III and the following courseware was implemented:

Arithmetic proficiency training program (Grades 2 to 9)
Elementary reading skills, CCC (Grades 3 to 6)
WRITE, Poughkeepsie schools (Grades 4 to 9)

Although the early achievement results of the students were excellent, various operational problems were encountered. The frequency of system breakdowns and the slow response time began to erode teacher support of the program. Also, the system did not have as many terminals as were needed and staff were not available to maintain the courseware.

Consequently the system was replaced late in 1976 by a CCC A-16 system supporting 64 CRT terminals. This delivers the CCC elementary mathematics, reading, and language curricula to all students in grades 4 to 8 in five schools. During the evening hours it is used for adult programs and runs the adult reading, mathematics, and language courseware.

In this setting the program now appears to be operating quite satisfactorily. The number of terminals available and the response time, which is less than two seconds, are considered to be more important than the facility to alter the courseware. Teachers dislike classes fragmented throughout the day but are willing to accept classes scheduled in two halves, as is required with a group of 16 terminals.

The teaching of basic skills is considered to consist of three steps. The first of these is the introduction of the concepts to the students on the basis of their readiness for them and in a sequence such that prerequisite skills have always been covered. This is done with the aid of the blackboard, visual material and printed matter. The teachers consider that no computer can supply the interaction necessary.

In the second step, however, that of giving drill and practice to achieve greater understanding and gain mastery of the concept, the computer is seen as being better able to individualize the material, mark answers and give immediate feedback. Using the CCC materials with a class of 30 students, the computer is daily monitoring 840 skill strands at the same time.

The third step, applying the skill and using it to master more complex concepts, is again seen as best carried out by the teacher.

The use of this type of CAI has had a dramatic effect on the achievement scores of the students involved: it has reversed a 16-year decline in achievement scores, which previous projects designed for the purpose had failed to accomplish. The mean achievement level of Los Nietos students is now approaching the national norm.

A longitudinal study using the California Test of Basic Skills was carried out with those students who were in grades 4 and 5 in 1974, most of whom participated in all three CAI curricula for three years. The results for grade 4 were:

	1974 means	1977 means	Mean gains
Mathematics	3.4	7.5	4.1
Reading	3.0	6.4	3.4
Language	3.2	5.9	2.7

The grade 5 students showed still larger gains:

	1974 means	1977 means	Mean gains
Mathematics	3.4	8.2	4.8
Reading	3.5	8.0	4.5
Language	3.2	7.5	4.3

Without the computer assisted instruction the mean gain which would have been expected over this period was 2.1, or 0.7 per year.

Although all the effects of the implementation of CAI are hard to measure, it is also considered that the reduction in truancy and vandalism to school property is in part due to the project. Students make intensive use of the computer terminals both before and after school hours, and teachers report that those who have been the most difficult to handle appear particularly attracted to the medium of CAI.

Crandall (1977), in an attempt to explain why CAI has been so successful in the Los Nietos School District, advances a theory of "locus of control". This term refers to how a student perceives himself controlled. An internally controlled student sees that achievement is commensurate with effort and that goals set for oneself can be reached, while the externally controlled student believes life is controlled by destiny, luck and the intervention of people more powerful than himself. Studies have shown that low achieving students and those from minority groups are usually in the latter category. In such cases re-inforcement in learning activities is not effective as the student does not perceive a causal relationship between his actions and the feedback that occurs. Crandall believes that computer assisted instruction is an effective medium for building internal control in those students in whom it is lacking. The features of CAI which effect this are the immediate feedback, the lack of external variables to which a student might attribute success or failure, the specific directions given by the computer and its low tolerance for any deviation from them, the one-to-one relationship between the learner and the terminal, and the success which the student experiences on most CAI courseware. Once such students become internally controlled they begin to make rapid gains in achievement, and this accounts for the highly significant growth in mathematics and reading skills.

However, whatever the reasons, the Los Nietos School District has found drill and practice CAI to be a very effective means of instruction in a setting where racial integration is taking place and teachers are faced with the task of educating groups with a wide range of experiences and abilities. In such a setting, where the need for individualization is great, the use of CAI is expanding, with over 1000 terminals in use in the classrooms in Los Angeles County alone.

TICCIT

Description of the System

Between 1960 and 1970 the computer industry expanded very rapidly, and there was a corresponding increase both in the number of computers in use in schools, from approximately 200 to over 1250, and in the amount spent on them, from $49 million in 1962-63 to $352 million in 1968-69 (Comstock, 1972). Computers were viewed as the emerging technology with major implications for education. At the beginning of the 1970's however, although the computer had become a valuable tool in educational research and school administration, and although many courses were given on computers and on how to write programs for computers, there were few direct applications of the computer to transmit instruction.

This situation existed in spite of the fact that the potential of the computer for individualizing instruction had been demonstrated in projects ranging from elementary arithmetic to college level physics. Certain studies had shown significant differences in achievement in favor of CAI as a supplement to traditional instruction, while others had demonstrated an improvement in teaching efficiency with students taking less time to learn a given amount of material. Further, students' attitudes towards CAI had been favorable.

A variety of reasons were advanced as contributing to this reluctance to adopt CAI. These included inadequate funding for CAI research and development, teacher resistance, the need for major demonstration projects with national prominence, and costs.

It was against this background, and as a small cost-effective alternative to the larger CAI systems planned at that time, that the TICCIT (Time-shared, Interactive, Computer Controlled Information Television) system was planned.

Initial developments were started in 1971 by the MITRE Corporation, aided by a federal grant, and in conjunction with the University of Texas. The MITRE Corporation was concerned with the hardware and software while the courseware was developed at Austin, Texas, and later at Brigham Young University in Utah.

The TICCIT system has three features which, taken together, distinguish it from all other CAI applications. First, it makes use of already available hardware, and combines both mini-computers and television technology in the system in order to keep the costs down. Secondly, it is a system in which the learner has control of his own instruction; it accepts student directions regarding the topic to be studied, the sequence of units within the topic, and the difficulty level. Thirdly, it is not a supplement to classroom instruction, but is a mainline system delivering all the instructional materials for a course.

The basis for the system is off-the-shelf technology that is readily available for purchase. At the center are two linked Data General Nova 800 mini-computers, one having a larger memory (approximately 64000 words) and acting as the main processor, the other performing the task of terminal handler. These two processors control five Century 114 disks, each with a capacity of 12 million words of storage. The disks containing courseware and student data are controlled by the main processor, while one containing information for generating course graphics, and an optional one for audio, fall under the control of the terminal processor. There are also two small disks, a card reader, a line-printer, and a magnetic tape unit on the system.

The TICCIT terminal is basically a Sony color television set to which is attached a special keyboard. The terminal is interfaced to the computer through a special piece of hardware built by MITRE. Seventeen lines of 43 characters can be displayed in seven different colors or, if the screen is used for a graphics display, the maximum dimensions are 204 points in the vertical direction by 403 points horizontally. Characters are controlled by the computer, and as many as 512 can be defined for use at any one time. Digitized audio messages and full color videotapes with sound can also be received at the terminal, although the latter have to be mounted individually by an operator.

The keyboard consists of three distinct sets of keys. The main set in the centre of the keyboard is similar to that of a standard terminal, except that the letter keys have associated with them an additional set of common mathematical symbols. On the left side is a block of keys which allow the positioning of the cursor and the editing of entries; while on the right are 15 keys which represent a student's choices in TICCIT's teaching strategy.

The system will support up to 128 such terminals.

The software which enables so much to be carried out on a system of this size, consists of a set of well written, efficient machine code programs which make maximum use of the hardware. These perform five distinct functions. The operating systems and application software run a time-sharing facility with a time slice of 79 milliseconds, process student entries, and keep student records. Software for data entry and courseware processing is concerned with the needs of the courseware author; programs for data entry partially automate the task of entering the displays, while courseware processing programs assemble these into a form ready for delivery to students. Finally, a set of programs provide utility services such as disk management.

The TICCIT system is a mainline system, where the students learn all the material required for a course at the terminal. Further, it is a learner-controlled system in which the student has a certain amount of choice about the sequence in which he will complete the course. Hence, when a student begins a course, the first material presented is a series of maps.

The first of these is the unit level map which presents the topics to be covered in the course. These can be considered as equivalent to chapters in a text book. For example, an algebra course on the system contains four units: arithmetic review, rational expressions, linear equations, and polynomial expressions.

Once the student has chosen a unit, a map of the lessons within that unit is shown. Again the student is asked to make a choice, causing a segment map to be shown. A segment contains the instructional material for one objective, and it is at this level that instruction takes place.

Each map is arranged in a hierarchical structure depicting the interrelationships in the material, and is color coded. Green represents an item mastered, red an item failed, and yellow an item in an intermediate state where not sufficient work has been done on the material for a decision to be made. When all the units in a course map are green the student has completed the course.

At the segment level there is again a certain amount of learner control, with the choices not now limited by items on a map, but by options available through the use of the special keys on the right hand side of the keyboard. Each one of these keys represents a command such as EXAMPLE, or a modifier to a command such as EASY or HARD.

The student has the choice of seeing an explanation of the OBJECTIVE; or the RULE, which is the tutorial part of the segment; or examples of its application, EXAMPLE; or the student may try problems, PRACTICE. The difficulty level of all of these can be chosen through the EASY and HARD options, and further clarification can be obtained through the HELP command. The student may also seek advice at any point by using the ADVICE key, or this may at some points appear automatically as the system detects a student's strengths and weaknesses. A student may request one of the tests at any point.

Using these commands a student examines and learns the material to whatever depth he chooses. The only requirement is the passing of the lesson tests and the mastery tests in those segments where such a test exists.

The fact that the student has this extent of control over the instruction imposes restrictions on the author of the courseware, since it creates a rigid structure into which the author must fit the learning materials. The course must first be divided into units, then each unit into lessons, and finally each lesson into segments. At each stage hierarchical maps must be constructed and entered into the computer system. Data entry software facilitates this, and most authoring activities can be carried out on the standard terminal while the time-sharing system is running.

For each segment, files stating the rule or concept to be learned and instances of the rule must be set up at two different levels corresponding to the EASY and HARD options. Further, detailed materials are needed for every item as responses for the HELP command; and test item banks are required for each lesson and for those segments for which the author considers mastery should be demonstrated. Since a student is allowed to take a test several times a considerable number of questions are required. Various formats other than multiple choice are available.

Color and the use of graphic displays can be used throughout the courseware to provide attractive material, highlight key points, and keep student attention. The production of graphics is greatly facilitated through the use of a graphics digitizer, a modified TV camera which scans a drawing and places a digitized representation on one of the system disks. This can then be examined later at a terminal, sections magnified using an editing program, and minor changes made. With 10,000 pieces of graphics material either existing or under development, this amount of automation contributes greatly to the courseware production process.

The extensive materials required for the mathematics and English language courses were produced and implemented by design teams each consisting of six members: a subject matter expert, an instructional designer, an instructional psychologist, an authoring assistant, a packaging specialist, and an empirical design technician.

Five full community college courses, three in algebra and two in the fundamentals of English composition, were developed using this systematic approach. They were brought into use in two colleges, the Alexandria Campus of Northern Virginia Community College, and Phoenix College of the Maricopa County Community College District.

Evaluation of the TICCIT Project

An evaluation of the TICCT program involving over 5000 students from these colleges was later carried out by Educational Testing Service. Comparisons were made between classes taught primarily by computer and sections of the same course taught by lecture and discussion sessions. These focused on four aspects of student performance: achievement, completion rate, attitude, and student activities. Assessments were also made of faculty acceptance, and the role of faculty in courses with mainline computer assisted instruction (Alderman, 1978).

Findings indicated that the TICCIT program had a significant positive impact on student achievement. Students did not consider the program impersonal, but their attitudes surpassed those of students in traditional classes only when the instructor took a very active part in the course, explaining difficult material and holding small group discussions to supplement the CAI curriculum. There were, however, dramatic decreases in course completion rates, indicating perhaps that these students were unable to manage their own learning; only those students strong in the subject area initially benefitted substantially from the courses. The activities of both students and teachers changed considerably.

Students spent less time on the course, all of which was on the system, than their counterparts in the control group who spent the greatest part of their time on homework assignments. There was no sequence observed for students' use of the learner control features, primarily because the RULE and EXAMPLE commands were seldom used. Students concentrated on PRACTICE problems because they received feedback which either confirmed a correct response or gave remediation for an incorrect one. Use of the TICCIT program did not alleviate students' needs for the assistance of an instructor, but generated a greater demand for individual attention. Instructors spent much less time on preparation and conducting classroom sessions, and devoted it instead to counselling students on course content and examining their performance on mastery tests. There was no teacher resistance to the installation of the TICCIT system and attitudes did not change over the two year evaluation period.

A more general conclusion from this study was that computer assisted instruction by itself guarantees no magical solutions to the problems faced in education. Outcomes of its use depend on the instructional design of the curriculum materials, on the manner of implementation, on the nature of the student population and on the role played by teachers. The computer alone is only an alternative means of delivering the instruction; its strengths lie in its capabilities for providing feedback on student performance and its potential for engaging students as active participants in their own learning.

Further Developments of TICCIT

From the outset, one of the main goals of the project was to produce a commercially successful computer-based instructional system. Hence, following the major demonstration in the community colleges, the MITRE Corporation, a non-profit organization, sought a commerical outlet for the system, and in late 1976 the Hazeltine Corporation acquired the rights to TICCIT.

However, even before this time the MITRE Corporation custom-designed and installed systems at two military sites, North Island Naval Air Station in San Diego and the Cecil Field Naval Air Station in Jacksonville, Florida. Systems were also installed for two special education applications at Amherst, New York and Washington, D.C. Reports on its use for military training indicate course completion times reduced by as much as one-half.

In Amherst a specially designed system was used to deliver computer based instruction to homebound handicapped children. They received interactive instructional displays directly on their home television sets and interacted with them through a special keyboard and telephone link to the system's central computer. The project, serving 100 families, was the first to attempt such large scale home delivery of CAI.

Another innovative special education application is at the Model Secondary School for the Deaf in Washington. Here the TICCIT system is being used both for delivering instruction and for facilitating communication between deaf students. The system is integrated with the school's closed circuit cable television to provide a wide range of services. The terminals are used interchangeably for computer generated instructional displays, commercial and local television broadcasts, and terminal to terminal video communications.

All three of the original installations are actively used for courseware development, delivery of instruction, and research. They have expanded their hardware systems as well as their applications.

At Northern Virginia Community College the TICCIT system has been fully integrated into the campus Learning Resource Center where it continues to be used to teach both mathematics and English. Courseware development taking place in the college includes a new mathematics course and applications in biology, chemistry, and poetry.

The system at Phoenix College has been fully integrated into the freshman English program, and is also used to deliver instruction in remedial mathematics, fire science, and medical terminology.

When it was no longer needed for intensive production of courseware for the college level courses, the system at Brigham Young University was moved to the Learning Center in the library building. Here it is used for research, courseware development, and instruction in a variety of topics including English, mathematics, reading, nursing, linguistics, German, and Spanish.

It was initially argued that all instructional material could be presented using the one set format and that this technique maintained a certain standard in the courseware. However, since such diverse subject areas as algebra, spelling, music, and sonar buoy identification have been implemented, a need has been found for other instructional strategies, in particular simulation. While the original authoring procedure (APT) still exists, a new high level authoring language (TAL) has been developed. This has greatly improved the flexibility afforded authors, while at the same time retaining the capabilities of display construction and response analysis.

Other improvements to the system include the implementation of a less restrictive model of administering the tests in which the instructor can control the parameters, and inter-terminal communication features such as electronic mail for passing messages between instructors and students.

While researchers at Brigham Young University consider that technological advances have already overtaken the original TICCIT configuration, they maintain that the developments in videodisc and microcomputer technology will play important roles in future TICCIT-like systems. Videodiscs will greatly improve the system's capability to present pictorial information and rapidly access instructional TV segments as part of complete courses. In conjunction with microcomputers they could meet the CAI requirements in locations where only a few terminals are needed, thus eliminating telephone line connections to a remote computer. Research on such systems is taking place both at Brigham Young University and at the World Institute for Computer Assisted Teaching (WICAT) established near the campus in 1977 by Bunderson, who initially directed the development of TICCIT courseware.

There is on the present system, however, a considerable pool of courseware which, although originally written for college level courses, is also suitable for school use. It could not be used at this level under learner control as the number of maps, options, and special keys needed to interact meaningfully with the materials would prove too difficult. Nevertheless, the content is good and structured for computer presentation. One criticism is that there is an over use of graphics, with the illustration often contributing no additional information to an instructional display. This situation has occurred because pictorial information is relatively easy to incorporate into the courseware with the graphics digitizer and its associated software. Such illustrations might, however, be more appreciated at school level.

Minnesota

Although there have not been any specific CAI projects of prominence in Minnesota, there is in the State a general awareness of the impact of computers, resulting in their quite extensive use in many administrative functions in the schools and in a demand for instruction about them in the classroom. This may to some extent have stemmed from the fact that several large computer manufacturers have main offices in Minneapolis, but whatever its initial cause the school systems have responded.

TIES

As long ago as 1967 TIES (Total Information for Educational Systems) was established and funded by the Minnesota School Districts Data Processing Joint Board which consisted of 20 school districts in Minnesota with a total enrollment of 112,000 students. By mid-1976 the TIES organization was serving the administrative, instructional and research computing needs of 50 school districts, and by 1979 the number of school districts had expanded to 55, involving approximately 300,000 students and 50,000 staff in 330 different schools. These services are provided by a central staff of 60 members who belong either to the group concerned with computer operation, user manual production and in-service training, or to the design and development division responsible for new systems and the enhancement of existing ones. This latter group is in close contact with committees of users who help design applications, monitor their testing and provide feedback at each stage. The organization is such that neither size of school district nor distance from the central facility effect the service obtained.

Each district is responsible for its own data base for the administrative applications. It is an integrated file structure which is manipulated on-line using both CRT terminals and mark sense card readers located usually in the district offices. This places the responsibility for the correctness of the data on the individual school districts.

Applications programs, written and maintained by TIES staff, access the data base. These fall into four groups, concerned with student data such as scheduling, class lists and mark reporting; financial systems;

research applications; and computer managed instruction and computer enhanced instruction. All classroom activities fall into the last group.

A further program also exists which allows the extraction of information and reports which are not part of the standard system.

Together these programs provide a Total Management Information System (MIS), a tool enabling the teachers to maximize learning through a well designed program of activities for each student based on individual needs.

The hardware supporting this extensive system is a powerful Burroughs configuration with considerable storage available on disks and tapes.

CAI was first provided in 1969 when a Hewlett Packard 2000 series computer with 16 ports was installed. This series of computers has been used fairly widely for CAI in the schools (Academic Computing Directory, 1977), as the manufacturer implemented on it some of the Stanford drill and practice programs in elementary mathematics and reading. To these TIES added many more CAI programs.

By 1974, three such Hewlett Packard systems provided 96 ports, and by the end of 1978 the number had been further increased to 180 by purchasing time on a state-wide time-sharing system.

In 1979, however, a planned reduction in this type of hardware support for CAI in the schools was commenced which will gradually reduce the number of ports available to 96 by 1983 (Holznagel, 1979). Several factors taken together caused this decision to be made. The Hewlett Packard 2000 series is no longer in production and is rapidly becoming obsolete, telecommunication costs are rising and may soon include within city billing, and microcomputers are becoming increasingly available at rapidly decreasing costs and with a better version of the BASIC language than that on the 2000 series. Nevertheless, a continuing need for time-sharing services was identified for such applications as student guidance programs, information retrieval, teaching of languages other than BASIC, and as a library and distribution source from which programs can be down-loaded to the microcomputers which are being phased in.

TIES, then, sees the needs of its member districts for CAI applications best served by a mix of microcomputers and time-sharing ports.

Overall, the key to the success of TIES lies in the effective provision of software necessary to meet the needs expressed by the school districts using whatever hardware is appropriate, and in constant sensitivity to both the priorities and everyday requirements of its users. This latter function is carried out through user committees and the information system coordinator employed by each district. Also very important are the extensive manuals and documentation, in-service training, and the availability of TIES staff to school district personnel at all times. TIES is a true network, both of computer systems and of people communicating effectively.

MECC

Another organization which has contributed to the general awareness of computers and their more widespread use in schools in Minnesota than in other states is the Minnesota Educational Computer Consortium (MECC).

Much newer than TIES, MECC was formed in 1973 by all levels of education in the state. Its members include the University of Minnesota, the

State University System, the Community College System and the State Departments of Education and Administration.

Its function is to co-ordinate and provide computer services to students, teachers and educational administrators thoughout the state. In order to carry out this large undertaking it employs a staff of approximately 75 and also draws upon the resources of its member systems.

In its co-ordinating role MECC maintains a long-range master plan for educational computing and develops shorter term biennial plans, both in close collaboration with its users, as one of the major premises on which MECC was estabished was that it be user controlled. It also seeks to achieve economies by negotiating bulk buying contracts for the purchase of computer and communications facilities, and by the common development of software systems.

For example, one of its recent projects in this area was to assess the potential for educational uses of about 15 different microcomputers, and as a result to arrange a volume purchase agreement for the schools and colleges to acquire APPLE II computers. To date about 1000 microcomputers have been bought by the school through this contract. In this manner MECC facilitates while not dictating compatibility of hardware, and also provides software support and program exchange mechanisms.

On the service side there are three divisions which evolved as the needs of the member systems were identified. The divisions are Instructional Services, Management Information Services and Special Projects.

The first of these, Instructional Services, manages and operates the state-wide time-sharing computer network. At present, approximately 2000 terminals located across the state in most public schools and all community colleges and universities have access to the network. Most of these are simple Teletype terminals. To accommodate this number of terminals several computer systems are used. MECC operates its own computer system which provides 375 ports and also acts as a broker for services supplied by the University of Minnesota's CDC 6400 computer and TIES Hewlett Packard 2000 systems. These latter systems make another 282 ports available.

Applications on the network range from simple drill programs for skill improvement to complex simulations of historical events and guidance systems. In all, over 950 instructional programs have been implemented or developed and are available to all the users of the network to supplement curricula at elementary, secondary and college levels.

The implementation of this system has certainly been successful in equalizing access to instructional computing facilities by dramatically increasing their availability to the rural areas. In 1973-74 only 14% of students in such areas had access to instructional time-sharing, while after the first year of operation of MECC this figure increased to 46% (Brumbaugh, 1975).

For the purposes of Management Information Services the state is divided into seven regions, two of which cover the metropolitan areas of Minneapolis and St. Paul. One of these is in fact the TIES region. Each regional group is responsible for the delivery of services to the school districts in the region. These relate to finance, personnel and payroll, and student and instructional management areas. MECC has the responsibility for the development and implementation of applications and systems software. The advantage is that in this way each school district will have access to comprehensive, standardized software without the prohibitive cost of developing such systems on its own. In this application MECC has again been able to facilitate the acquisition of the necessary hardware through a bulk buying contract with a discount of nearly 40%. The installation and servicing of the equipment is also carried out by MECC.

The Special Projects division initiates, implements, facilitates and manages a wide range of activities related to the use of computers in education. Projects have used a variety of delivery systems from microcomputers to the PLATO system, and have been supported by the National Science Foundation and the National Institute of Education. This division also carries out evaluation studies to learn more about the uses of computers in education and to measure the impact and effectiveness of computer based systems.

In the provision of its services MECC considers two factors to be important to their effective use, namely documentation and personnel training. Providing the former is a major task for the MECC staff, while the latter is addressed by running over 300 workshops annually to explain the facilities available through the instructional network and to allow for the exchange of ideas between users.

There is no doubt that MECC has made a significant contribution towards greater use of computers in the schools in Minnesota. In the first four years of its existence the percentage of school districts with access to instructional computing grew from 17% to over 70% (Haugo, 1978). To the present time, however, the uses to which the facilities have been put have been directed much more towards various aspects of computer literacy than CAI. Nevertheless, some CAI is in use and, with its organizational structures and pool of staff with expertise on computer uses in education, Minnesota is likely to be in the forefront of the implementation of CAI in the schools on a large scale when this becomes viable in the near future.

The review of CAI projects in the United States has covered those which are of some considerable size and have been sustained over a period of years, and have also produced materials which have been implemented in a school setting or could readily be applied to teaching at this level.

The projects were also chosen to illustrate the very different types of hardware and software systems that have been used and how these, and the overall guiding philosophies of the projects, have effected the development of the courseware and the methods of delivering it to students.

Certain findings, however, are consistent over the projects. These include two very important considerations, namely that students do learn from CAI materials and that they do on the whole enjoy learning in this manner.

Other CAI projects do exist, but it is surprising how few there actually are at the school level when a close examination is made (Thomas, 1979). Computers are used far more for administrative and management functions, while the area which appears to be the most rapidly expanding at the present time is that of computer literacy. It could be, however, that this is a necessary precursor to the introduction of CAI on a larger scale (Molnar, 1978).

Nevertheless, it is in the United States that most of the development of CAI has taken place. Although there may be relatively little CAI in use there, in other countries there is considerably less.

Europe

Although there has been comparatively less CAI in Europe than in North America, development programs were sponsored and financially assisted by national governments in the United Kingdom, Germany, and France during the 1970's. At the present time, new programs are beginning in the United Kingdom and France, and indications are that CAI will gradually expand, based largely on the use of microcomputers.

United Kingdom

The U.K. National Development Program in Computer Assisted Learning began in 1973 and extended to the end of 1977. At that time, approximately two-thirds of the 35 main projects had become institutionalized, in the sense that they were continued by their host institutions.

Typically, these projects did not attempt to provide any initial tutorial material using CAI. This was supplied by lectures, text books, or other resource materials. Students then used computer based modules in problem solving or simulation format to enlarge and consolidate their understanding of concepts, and to obtain practice in their application. The few projects that were at school level were concerned with the provision of information and statistical services in such subjects as high school history and geography.

The Schools Council supported a second program for the development of computer assisted learning materials prepared by teachers in a four year project from 1973 to 1977. These consisted mostly of simulations in science, economics and geography, and have been described by Lewis (1980). Some have been implemented on microcomputers and are available from CONDUIT (Reiners et al, 1979). A second three year project began in 1978 and includes a specific study of microcomputers in the classroom as a teaching aid. This will include the development of materials for remedial teaching, with drill and practice programs where necessary.

Computer assisted instruction using tutorial modules has been used in some of projects. Broderick (1974) reports a study in which it was used to teach biology. The Computer Based Learning Project at the University of Leeds has developed a number of programs to teach junior high school mathematics. These are of interest in that they incorporate procedures to adapt the instruction to student needs as determined by recent past performance (Hartley et al, 1976). At the present time, five terminals are used in one school. In Hertfordshire, a computer managed mathematics project has made use of some tutorial courseware. Programs to teach word attack skills to handicapped children have been developed at Edinburgh University, using a computer controlled slide projector and touch sensitive screen (Howe, 1979).

During 1979 there was an upsurge of interest in the use of computer assisted instruction for special education students. Various colleges and schools, particularly in the Birmingham area, are now engaged in the development of programs for this purpose. It is relevant to note that a comparable interest has developed at approximately the same time in both the United States and Australia.

In early 1980 the government announced a four year, nine million pound program, to follow up the first National Development Program. The intent is to concentrate on three areas, namely curriculum development, software, and teacher training. Indications are that much of the effort will go into the use of microcomputers, which at the present time are being quickly acquired by the schools. In late 1979 the Scottish Council for Educational Technology received from the Scottish Education Department a sum of three hundred thousand pounds for microcomputer equipment to be loaned to schools, and invited project proposals. By early 1980 it had received proposals totalling two million pounds, many for the use of microcomputer systems for interactive teaching in the area of mathematics and science.

Federal Republic of Germany

As in the U.K., the national project to develop computers and their application in the Federal Republic of Germany in the mid-70's received very substantial support from the central government. In the years 1971-1973 for example, the expenditure on computer assisted learning amounted to 30,000,000DM. Since education is the responsibility of the separate states, all school projects were undertaken as a cooperative effort by the two levels of government, and received further funding from the local governments.

Again, as in the U.K., comparatively few projects were at the school level. However, two significant projects were in schools, one in Saxony and one in Bavaria (Hallworth, 1974).

At Garbsen, near Hanover in Saxony, a Siemens computer supporting 30 display terminals was located in a primary school. Educational researchers and computer specialists worked closely with teachers in the school to develop CAI programs in mathematics, science, and English (as a foreign language). All CAI was regarded as supplementary to regular instruction; no attempt was made to use the terminals in order to teach all of the curriculum in a given subject area. Teachers were given release time for program development, and regarded CAI as a potential solution to the local problem of teacher shortage. All terminals were grouped in one room and were used by one class at a time, with students sometimes working two to a terminal.

In Augsburg, Bavaria, a similar computer in a secondary school supported 30 terminals. Again, project staff cooperated to develop courseware with teachers given release time for the purpose; and programs were developed to provide supplementary instruction in mathematics, science, and English. Groups of students used the terminal room for 25 minute periods.

The CAI project at the Stiftung Rehabilitation Institut in Heidelberg, although not in a school, is of some interest both because it is large and because it is concerned with the physically handicapped (Augsburger and Lampl, 1980). It has now been in successful operation for ten years as an integral part of an institution providing vocational settlement and social integration of the handicapped into the community. At the present time it still makes use of mainframe computers supporting display terminals. CAI programs are mostly of the drill and practice type, with tutorial elements and remedial branching. Subject areas include mathematics, economics, engineering, and finance.

France

Research in CAI in France began around 1965 at the Universities of Paris, Grenoble, and Toulouse. As elsewhere, it was at first slow to develop because of the high cost of computer time. Also, work on CAI was rarely regarded as significant to the career progress of researchers, a factor too often still unrecognized at the present time.

Hebenstreit (1980) has provided a comprehensive summary of CAI in the schools. The experimental introduction of CAI at the secondary level began in 1970. Participating teachers were given one year of training on a full time basis, 600 terminals were installed in 58 schools, and over 500 programs were made available. The careful planning ensured success and, in 1979, the government adopted a new five year program. This involves the training of more teachers, and the installation of 10,000 additional terminals in the schools.

From a North American standpoint, an interesting feature of the above projects in the U.K., Western Germany, and France, is the emphasis upon problem solving and simulations, and the use of CAI primarily as a supplement to regular instruction in the schools.

Another feature is the emphasis upon "institutionalization", particularly in the U.K. and France although, due to the different organization of education, it has been achieved in the first case by encouragement of local initiative and in the second case by centralized planning. In all three countries there has been a concern with costs. In Germany, however, this was sometimes not an evident concern at the project level and is possibly one reason why some projects have not continued. Another aspect of institutionalization has been the conscious effort to involve in the computer projects, on an ongoing basis of active participation, the teachers responsible for the regular instruction of the students. Where this involvement was in one case not achieved, an expensive project supported by highly competent computer personnel came to an abrupt and untimely end.

In all three countries there has been substantial government funding, from the national and/or state level. No projects would have been possible without such assistance. At the present time the renewal of such funding represents an affirmation of the importance of such projects to the school systems.

A recent feature, likely to become progressively more significant, is the increasing attention that is being given to the use of microcomputers. The reasons for this are explained later in the examination of present technological developments that are relevant to CAI.

Canadian Projects

In Canada six projects are of significance. The National Research Council, the Universities at Calgary and Edmonton, and the Ontario Institute for Studies in Education have been carying out research in CAI since the late 1960's, while work on a smaller scale and of shorter duration has been taking place at the Universities of Manitoba and Lethbridge.

National Research Council

As a federal agency the National Research Council (NRC) is not concerned with teaching and, therefore, not with the production of courseware. Its influence on the directions of CAI in Canada has, however, been considerable. Its role has been one of co-ordinating, making computing facilities for research and development available to all regions at the same cost, and attempting to introduce some standards for various aspects of CAI. It has also carried out considerable research on hardware for CAI, particularly in the area of multi-media terminals. In all these tasks it has continually sought to bring together representatives of both universities and industry.

The project began in 1966 when the Radio and Electrical Engineering Division switched its research thrust from radar to CAI. As early as 1967 a touch sensitive device had been developed based on ultra-sonic waves. Two sets of these were projected at right angles across a sheet of glass. If their paths were interrupted by a finger pointing at the glass the waves would be reflected, and the time taken would be measured and used by the computer to determine the exact point of interruption. This device has since been produced commercially and is used quite extensively in the PROMIS terminal in conjunction with a medical project in the eastern United States.

The project has continued to emphasize the need for an easy to use multi-media terminal for all CAI applications, and has regarded text-locked typewriter terminals and CRT's as only interim measures because they create too large a barrier between the user and the information the user wishes to obtain. To this end NRC has developed numerous devices over the years concerned with computer controlled image projection, computer controlled audio output, graphics, animation, and input devices for the handicapped. Its most recent research has used microprocessors in such terminals.

The use of a multi-media terminal implies that certain messages which are invisible to the user must be passed from the computer to the terminal, and to a lesser degree from the terminal to the computer. This is usually carried out by the use of non-printing ASCII codes. The NRC has produced standards both for the format of the messages and for the designation of the individual codes. The need for such standards is perhaps not immediately obvious, but they are essential to facilitate the exchange of courseware using multi-media terminal equipment.

To encourage the development of CAI in Canada the project installed a Digitial Equipment PDP-10 computer system in 1969 (Brahan and Brown, 1972). The system, regarded at that time as the most advanced and reliable time-sharing system available, cost approximately $1 million and was clearly outside the budget range of other Canadian projects. The computer supported 64 terminals and was dedicated to CAI research and development.

It was made available on-line at nominal charges across the whole country to groups interested in developing aspects of CAI. To encourage co-operation and the exchange of ideas and courseware, all materials implemented on the computer were available to all other users.

Starting in 1972 the NRC in consultation with other CAI projects drew up specifications for a new CAI authoring language. These were completed in late 1974 and the language so defined has now been implemented on the PDP-10 system and is available on an experimental basis to its users. Named NATAL-74, this language is currently being implemented on an IBM computer, on a Honeywell machine, and on a microcomputer. Numerous CAI materials, ranging from programs used in commerce to programs for handicapped learners, have already been translated into NATAL-74. A computer managed instruction system is also available.

An account of current NATAL-74 projects has been given by Brahan et. al. (1980).

Ontario Institute for Studies in Education

The first project to make use of the NRC PDP-10 system after it was installed in 1969 was that at the Ontario Institute for Studies in Education (OISE). This project had started two years earlier using a commercial time-sharing service on which the first version of OISE's authoring language CAN was implemented (Olivier, 1972). This language, which contains many of the facilities available in COURSEWRITER, although in an easier to use format for the author, has been through a series of refinements and has been implemented not only on the NRC PDP-10 computer but also on several computers owned by OISE over the years and on various machines in colleges in Ontario.

The CAN language has also been implemented on the University of McGill's computer system where it has been used to author courses for the training of teachers (Cartwright and Kolano, 1978).

The major courseware developments for which CAN has been used, however, have been in the area of remedial mathematics, primarily at college level. There are several important general considerations related to this courseware.

First, it is the only mainline courseware to be developed and used with a large group of several thousand students in Canada. Secondly, this substantial undertaking would not have been possible without the joint co-operation of NRC and OISE in the development of many aspects of the necessary software, and similar close co-operation between OISE and the community colleges in the specification of the courseware.

Initially the CAN language was implemented on the NRC PDP-10 and the courseware stored in this system. In order to access this without incurring high telephone line costs, network software was developed with OISE's smaller TSS-8 system acting as a multiplexor. The courseware could then be distributed to the terminals in the Toronto area through one high-speed telephone line to the PDP-10 in Ottawa. Late in 1975 OISE acquired its own PDP-10 system.

Courseware development actually began as early as 1969 when an analysis of the needs of the colleges was carried out. One of the areas identified was remedial mathematics and the task of specifying and building courseware for a full semester course began. Throughout the long process of development and testing a committee of college personnel guided the operation, thus ensuring a wide degree of acceptance. A measure of the success of this approach is that Seneca College and Algonquin College later bought their own computer systems to support the courseware.

A third area of particular interest is the structure of the courseware and the various techniques used to achieve individualization. The topic is divided into modules each containing four sections: tutorial, example, drill, and test. Within each module a statistical technique, first developed for industrial applications, is used to determine whether mastery is achieved (Wald, 1947). This prevents a student from having to complete a whole series of questions when it is obvious that the material is known. Further, the modular structure allows the actual course content to be under teacher control, where the teacher specifies the modules and their order of presentation, or under student control, where the student chooses modules from an index, or under computer control, where the computer automatically selects the next module based on student performance. In the latter case a skeletal structure is used with certain modules designated as nodes. A student progresses through these modules until failing to pass one. The computer then moves back in the hierarchy, presenting to the student those modules which are immediate pre-requisites of the one which was failed. When these are mastered, and in addition any of their pre-requisites not known to the student, the node module is presented again. As in the case of the mastery level criterion, this particular adaptive technique was chosen to allow the student to move as quickly as possible through the course without having to cover any unnecessary topics.

One disadvantage of this course is that in its initial implementation, completed in 1974, it was necessarily text-bound, using the teletypewriter terminals available at that time. Some colleges are now beginning to implement some of the materials on microcomputers, making use of the graphics facilities.

Meanwhile, OISE has turned its attention to developing courseware at the school level, particularly grades 6 to 10, although it is planned to develop materials for grades 1 to 13 in the areas of mathematics, science and English (Olivier, 1976). In this venture it is co-operating with the North York and Toronto Boards of Education in a manner similar to that used to develop the college materials. The North York schools already have approximately 30 terminals in operation and can access the existing remedial mathematics course. This material is, however, only suitable for the particularly bright school students.

University of Calgary

Another project which was among the earliest in Canada and also one of the first to use the NRC facilities was that at the University of Calgary. This project began in late 1968 and has, on the whole, made use of commercially designed hardware and software in order to concentrate its efforts on courseware development and teacher education. To this end, however, changes or additions to existent languages have been unavoidable at times and, more recently, it has also been necessary to engage in some hardware development, namely the design and construction of microprocessor based multi-media terminals.

The initial system purchased was a Digital Equipment Corporation TSS-8 computer supporting Teletype terminals. This was one of the first available general time-sharing systems based on a mini-computer. It was gradually built up to the near maximum configuration of 32,000 words of core memory, a 256,000 word disk, six DEC tape drives, and ports for 17 terminals. The 512,000 word disk originally planned for this system was never delivered due to the fact that at the time manufacturing techniques were not sufficiently advanced to build a reliable disk of this size.

This relatively small storage capacity strongly influenced much of the early development. First it necessitated the choice of the most economical language, with regard to the amount of memory required, for writing CAI programs. This language was FOCAL, a relatively high-level interactive language still available today although comparatively little used. Its main disadvantages for CAI applications are the lack of both character string and file handling functions.

Secondly, it was not possible to develop any mainline CAI programs or even many tutorial programs of significant size. Consequently a pool of adjunct programs was built up, mainly drill and practice type but including also some simulations. Randomly generated problems were used extensively, again to conserve storage space. The programs were mainly at school level and covered several subject areas including mathematics, English, chemistry and physics. One of the earliest programs written in 1968 was the Sumer game (or Hamurabi), often implemented on the microcomputers of today.

These programs were used experimentally in the schools by teachers who were also students taking courses on the use of computers in education. Any attempt to operate a terminal in a school where none of the teachers had any knowledge on the topic was invariably unsuccessful.

While programs are still actively developed in a wide range of subjects, two areas of concentration have gradually emerged. These are CAI for the mentally handicapped (Hallworth and Brebner, 1980) and CMI and CAI in reading at the elementary school level (Brebner et al., 1980).

Although initiated on the TSS-8 system these projects have been running since 1976 on a Digital Equipment Corporation PDP 11/70 system. The installation of this system allowed expansion in several directions. First, with 192,000 words of core memory and an 88 megabyte disk, storage restrictions were no longer a consideration. Secondly, the present configuration has 48 ports, enabling more terminals to be located in the schools. There are now approximately 25 in use in schools throughout the year. Thirdly, the system supports an excellent version of the BASIC language, with file handling capabilities which allow the keeping of student achievement records and the use of controlling management programs to deliver the CAI.

Work with the handicapped began in 1971 on a very small scale, using one Teletype terminal and programs originally designed for elementary school students. From this point the special needs of this population with regard to CAI have gradually been defined. These include a highly structured curriculum teaching immediately relevant social living skills, the shaping of behavior rather than a tutorial approach, and constant and consistent feedback.

Specific curriculum areas addressed have been money handling and shopping skills, and reading. These topics, and the physical handicaps of many of the students, have necessitated the design and development of multi-media terminals. Image projection is needed to display coins and bills and items which may be purchased. Audio is essential for teaching reading and giving feedback to those who cannot read. Many special input devices are required both to overcome physical handicaps and to facilitate concept learning.

CAI has proved to be a very effective method for teaching the handicapped population in many ways. These include the patient repetitiveness of CAI, the individualized instruction, and immediate feedback. A measure of its effectiveness is the fact that CAI is now an integral part of the education of students in the institute where most of the research and development has taken place and where seven multi-media terminals are now in daily use.

The second area on which emphasis has been placed, remedial reading at the elementary school level, began as a computer management system, with on-line testing of students, to monitor their progress on 329 behavioral objectives covering grades 1 to 8. When a student's working level is reached in the test materials a student summary report is available, and when testing sessions for a class have been completed a class summary may be obtained. This latter report groups the students by objective, and prints prescriptions both of teaching materials for those who must learn the objective, and enrichment activities for those who have already mastered it. During its first year of operation the system met with resistance from many of the teachers; but when they observed the improved achievement of students in those classes where it had been used, they were anxious to use it themselves. It has now been in regular operation for six years throughout the school of 450 students. During this time many CAI modules have been added as part of the prescriptions.

Education of teachers in the topic of CAI has always been considered of major importance for its introduction into the schools, and a series of courses and graduate degrees have been offered for the past ten years. In 1980 in-service courses on computer literacy were added.

Microcomputers are seen as the future delivery systems of CAI, probably forming the basis of interactive multi-user systems and supporting multi-media terminals. Videodiscs are also seen as adding a new dimension to the courseware which can be presented and the main thrust of the project's research is turning to these two areas.

University of Alberta

The final long standing project in Canada is that at the University of Alberta. It began in 1968 and, as in the case of the University of Calgary project, its directions have been determined to a large extent by the hardware, an IBM 1500 system. When acquired in the late 1960's this system was the most advanced available for CAI applications. It supported a group of multi-media terminals, each consisting of a CRT screen capable of displaying 640 characters, an image projector, an audio device, a keyboard, and a light pen (Hunka, 1972). Initially, there were eight such terminals, but the facilities were gradually expanded to finally support a maximum of 32.

The language supplied with the system was Coursewriter II, to which the University of Alberta and other IBM 1500 system users added several powerful functions to aid the courseware author. These were mainly concerned with answer analysis and the construction and use of graphics.

The comprehensive facilities available, the high rental costs of the system and, above all, the fact that the terminals had to be located within a few feet of the computer were the factors which affected the courseware developed on the system. Most of the courseware has been tutorial type, has covered a fairly large section of curriculum, in some cases a complete course, and has been directed towards a university level audience. Because terminals attached to the system could not be placed in schools very little has been done at this level.

Some of the earliest and best known programs were developed in conjunction with the Faculty of Medicine for second year medical students. These included a series on cardiology and a set of simulations on patient illness and treatments. Later programs in the area of pharmacology were also written.

Another university level course which has been in operation since 1975 is one in introductory statistics. The course material, which takes approximately 60 hours for the average student to complete, needed 2500 man hours to fully develop and contains 100,000 computer instructions.

A further course for education students available on the system was one obtained from Penn State University on the identification of handicapped children in the classroom.

Teaching materials for students at the Northern Alberta Institute of Technology have also been developed and run on the system.

In a typical academic year approximately 24,000 hours of terminal time would be used, 90% of it student time on the above and other courses.

Some materials at the school level have been developed. However, students using these programs have always had to be bussed to the CAI laboratory at the University; they have therefore not been used by a large group of students, nor been tested over a considerable time period. Further, it has not been possible for them to become integrated into the general school curriculum.

Such programs have included a 20 hour course on French for grade 10 and a variety of materials for use by the deaf. Among these latter materials have been units on basic reading skills for grade one, and on using a ruler for students enrolled in a vocational training program.

More recently a Teletype terminal has been located in a school for the deaf and attached to the main university computer, an Amdahl 470/V6 (Kearsley and Montgomerie, 1978). On this terminal the students have been using arithmetic drill and practice programs, many of which were originally written in Manitoba. Changes and additions have been made, however, some due to the incompatibility of the two versions of the BASIC language, and others to improve the instructional design.

Changes taking place at the present time indicate that the project will become more involved with research and development of CAI at school level in the future. The IBM 1500 system has become obsolete and is no longer supported by IBM. Its use, therefore, was discontinued in April 1980. In its place the University is installing a CDC PLATO system in the main computer center to support the university level CAI requirements, and a Digital Equipment Corporation VAX system in the Education Faculty to enable this project to continue. From this system there will be no problem in locating terminals remotely in schools or linking them at times into the NRC network. In addition the project has been investigating the potential of microcomputers, particulary as delivery systems for CAI in the remote northern areas of the Province.

University of Manitoba

In Manitoba a CAI project began in 1974 and, since its inception, has been directed towards the school level handicapped population. It is supported financially by both the Provincial Government Department of Education and local School Boards in the Winnipeg area, and is co-ordinated from the University of Manitoba, (Sandals, 1978).

The hardware used is a large time-sharing CDC Cyber 171 system supporting many other applications in addition to the CAI. This project is in fact one of few successful ones running on a system not dedicated to CAI. To date the CAI terminals attached to the system have been simple hard copy or CRT terminals. It is, however, planned to evaluate a microprocessor based multi-media terminal developed by the National Research Council and incorporating a Bliss symbol board and a voice synthesizer.

The programming language in which the courseware is implemented is BASIC. The version of this language on the Cyber system contains more than just the fundamentals of the language, but lacks some of the features useful for CAI applications which are available in other versions for other machines.

The courseware consists of over 200 programs, mainly of drill and practice type but including a few in tutorial mode. They deliver instruction at approximately 1500 skill levels, in mathematics and language hierarchies which span both elementary and secondary levels. As the programs are designed to be used in an adjunct manner, both manuals describing each program in detail and file card indexes were developed, to enable teachers to easily identify those programs suitable for their students' needs. Further, in-service courses are run to acquaint teachers and other school personnel with basic facts about computers and how to access the CAI materials.

Most of the materials have been designed and programmed by teachers and graduate students in education during the summer months. That such students already had a good knowledge of computer programming is due in part to emphasis placed on computer science as a subject area in the Manitoba schools, and this in turn is in part due to the fact that the Manitoba Government took over a bankrupt computer bureau in the early 1970's and has used its computer system for educational purposes.

In the 1979-80 school year the programs were being used in 13 schools mainly by students with special needs. Among these schools were a residential school for the deaf, a high school for retarded adolescents, and a juvenile correctional center.

Further expansion of this project and also the development of microcomputer based CAI systems, are planned for the future. In connection with the latter aim the project is experimenting with a Radio Shack TRS-80 microcomputer.

University of Lethbridge

At the University of Lethbridge a small scale CAI project has been in operation for some years. This is run, not from the Faculty of Education, but from the Computer Center. The project began when some of the Stanford drill and practice materials were implemented on the Center's Hewlett Packard 2000 computer and a few terminals were placed in schools to access these. The results have been consistent with those found elsewhere; there have been significantly faster rates of progress by those students using the terminals, and a higher level of mastery is also evident. In 1977 the Computer Center installed a Digital Equipment Corporation System-20, but the project has continued to supply four terminals to the elementary schools during the 1979-80 year.

Except for that at the National Research Council all of the Canadian projects reviewed, including those in Alberta, have been initiated by and operated from departments of the universities. The main reason for this is that until now CAI has been in a research and development phase. Also, hardware has been relatively expensive. A survey of the Alberta school boards conducted in the summer of 1979 showed that there was practically no CAI in the schools and few of the districts were contemplating its introduction in the near future. Within the last few months, however, the situation has changed considerably, with microcomputers coming into the schools at a rapidly accelerating rate. Although they are not primarily being purchased for such applications, some CAI is beginning to come into use on them and is in this way being introduced, albeit at a very local level and solely on the initiative of the teachers.

CHAPTER 3

PRESENT TECHNOLOGICAL DEVELOPMENTS RELEVANT TO CAI

Technological Change and CAI

The review of established CAI projects has indicated the feasibility of CAI, and its general success in producing effective learning for a variety of learners and a wide range of subject areas, frequently in a shorter than usual time. It has also indicated that CAI produces a generally higher motivation in the learner, sometimes with an apparently increased attention span. The review has also shown certain conditions which appear important to the success of the project, for example use of a dedicated computer; it has indicated the importance of enthusiasm and local control by teachers if a diversified project is to be well accepted; and it has indicated a trend towards fuller and more effective use of graphics and multi-media instruction.

At the same time, when the possibility has arisen of the establishment of a CAI project in schools on a permanent basis, there has been a general concern with costs. Invariably, in the first instance, the term "costs" has referred to the costs of computer hardware.

The established CAI projects have obviously made use of technology which was purchased and/or devised several years ago, sometimes as many as ten years ago or more. Yet, as suggested earlier, some very rapid technological changes are at present taking place which appear likely to have a significant effect upon the future of CAI. Two such changes relate to both computer hardware on the one hand, and to communications on the other. Both give promise of cost reductions.

The question is, will computer hardware become sufficiently inexpensive for CAI computers to be placed in schools, or will communications become so inexpensive that it will be more economic to have a large central CAI computer, with terminals in schools attached by communications lines?

One answer has already been given. Wagner (1976) estimated that, in 1975, central processing units cost only 0.5% of their cost in 1960 and were both more powerful and more accurate; mass storage in 1975 cost only 2% of its cost in 1960 and was both faster and more powerful. Further, he estimated that by 1985 these costs would be approximately 20% and 10% of the 1975 costs respectively. On the other hand, communications costs in 1975 were 61% of 1960 costs; and it was estimated that by 1985 they would be 53% of 1975 costs. It is clear that the smallest decrease is represented by the communications portion of the total cost of computing.

A recalculation in 1979 might well lead to a still lower estimate for computer hardware by 1985. Certainly, there is no reason to believe that the projected relationship between reduction in hardware and communications costs has altered in favor of the latter. However, in both fields the technological changes are very rapid, and have far reaching implications for CAI.

In yet a third field, relating to video equipment, developments during the last 12 months appear likely to give a new dimension which again could lead to significant changes in the nature and potential of CAI programs.

This section of the report is therefore concerned with the development of microcomputers and their use in CAI, the use of multi-media CAI stations and videodiscs, and developments in communications which are potentially important for CAI.

Microcomputers

The major CAI projects reviewed in the second chapter of this report all used a large mainframe or a mini-computer as the basis of their delivery system. However, it has already been indicated that delivery of CAI is at present undergoing significant changes due to the development of new technology. One such development relates to computers themselves: they were initially based upon tubes, then on transistors, and are now using silicon chips.

The central processing unit of a computer, in which all the arithmetic and logical operations are performed, can now be placed on a thin chip of silicon approximately half as large as a small finger nail. Memory locations to represent several thousand characters (or "bytes") can be placed on a similar chip. Other chips can be manufactured to control input and output, convert codes, and display characters on a CRT. When they are produced in quantity, such chips are quite inexpensive; and when appropriately assembled on boards, connected to a power supply and provided with the necessary software, they can make a small and inexpensive microcomputer. Such microcomputers are becoming more powerful every year, so that some are now the equivalent of a mini-computer of the type used in the TICCIT project. They are also becoming cheaper: hobby and home computers are already commonplace, small business computers are appearing in quantity, and a personal computer small enough to be held in the hand will probably be in production during 1980.

There is no doubt that microcomputers will be important in the future of CAI.

Microprocessors and Memories

In 1969 two companies, DATAPOINT and VIATRON, designed a very elementary computer for use in a terminal, and asked INTEL and Texas Instruments to implement it on a single silicon chip. INTEL succeeded and, although the speed of operation was too slow for use in a terminal, proceeded to develop the chip as the first microprocessor. This was the prototype of the INTEL 8008, a microprocessor which was four bits in length. The INTEL 8080 8-bit microprocessor quickly succeeded the 4-bit, and its increased power and demonstrated reliability have firmly established the microprocessor in a variety of fields. Moreover, the 8-bit microprocessors have become quite cheap: one of the more powerful, the ZILOG Z-80, could be purchased in quantity in 1979 at a unit cost of $6 U.S.

When developing a chip, the standard procedure has been to photograph a large-scale layout and use reduction processes to produce the necessary masks. It is now possible to use electron-beam technology on a production basis, and obtain line widths of as little as one or two micro-meters. As a result, 16-bit microprocessors are now becoming available which have the power of the central processing unit of a mini-computer. Moreover, these give only the first indication of what will soon appear in microprocessors, memory, input/output circuits, and analog to digital converters.

The power of a microprocessor is a function of its length (e.g. 4-bit, 8-bit, 16-bit), its execution time (e.g. one micro-second), and the number of memory locations it can address directly (e.g. 64,000 8-bit characters or bytes).

A Western Digital multiple chip set has been available for several years as a 16-bit microprocessor, using PASCAL as its assembler code and addressing directly up to 64,000 16-bit words. In 1978 INTEL announced the 8086, a 16-bit microprocessor capable of addressing one million bytes of memory. The Zilog Corporation had available in 1979 the Z-8000, with computational power approaching that of the PDP 11/45 mini-computer and an execution time of less than one microsecond. National Semiconductor Corporation is developing the NS 16000 family of microprocessors, the most powerful of which is expected to have a performance 20 times better than the INTEL 8080, and flexibility to operate in both eight bit and 16-bit modes. Possibly the microprocessor most comparable to a mini-computer central processing unit, however, is the Motorola MC 68000, which has the equivalent of 20,000 transistors on one chip. It is claimed to have 75% more power than a PDP 11/45, and can directly address up to 16 million bytes of memory. With an execution time considerably less than one microsecond, it can operate from a single five volt power supply. Of particular interest is the fact that, internally, the MC 68000 is a 32-bit microprocessor. The company had sample quantities available in late 1979, at a single unit price of $250 U.S., and expects to be in full production by late 1980.

The electronic memory used in microcomputers is also becoming cheaper and more densely packed on a chip. Random access memory (RAM) is used for reading and writing when developing or using a program, and until recently required eight chips to produce one thousand bytes. The industry standard is now 2000 bytes on one chip and this will increase to 8000, possibly by the end of 1980. The technology is now available to produce 32,000 bytes per chip. Also, access times are now considerably less than one microsecond: indeed, the fastest in 1979 was 55 nanoseconds, and 230 picoseconds is possible.

Read only memory (ROM), or erasable programmable read only memory (EPROM), is used to store information which must be kept on a permanent or semi-permanent basis. Such information consists, for example, of systems programs, high level languages, user programs in frequent use, or synthetic speech data. Again, the industry standard for memory chips of this type is 2000 bytes, and will increase to 8000 bytes at about the same time as it will for RAM memory chips. However, in early 1979 INTEL produced a chip which will hold 32,000 bytes and requires only a five volt power supply. A difficulty when using EPROM is that special devices are needed to enter data or erase it; future EPROMS, such as the new INTEL chips, will be much easier to use, being electrically alterable (EAROM), and could be a readily available part of any microcomputer.

Bubble memory has been much discussed as a comparatively inexpensive storage device, but is appearing rather slowly. As with RAM, data can be written into bubble memory or read from it; as with ROM, the data remain in memory when power is shut off. However, with access times in terms of milliseconds, bubble memory is much slower than electronic memory and more appropriate for auxiliary storage. A typical bubble memory device is approximately one inch square and three-quarters of an inch thick, and will contain more than 10,000 bytes. In mid-1979 INTEL began to market a 125,000 byte device, and Texas Instruments announced a similar bubble memory late in the year. Rockwell aims to develop for the U.S. Air Force similar devices, linked in sets of four to provide half a million bytes, and incorporated into a system having two million bytes, expandable to 40 million. Meanwhile, Bell Labs have announced an experimental bubble memory having at least one million bytes.

In effect, there are indications that bubble memory may soon be in common use. However, electronic memory is also becoming denser and cheaper, and it is not yet possible to determine which will eventually be most used for large scale storage.

At the present time, floppy disks are the main auxiliary storage device for microcomputers. Made of flexible plastic, these come in a standard eight inch diameter format holding 125,000 bytes on one side of the disk, and cost approximately $1000 for the drive and five dollars per diskette. A mini-floppy of five and one quarter inches diameter holds 60,000 or 70,000 bytes per side and costs approximately $400 for a drive and five dollars per diskette. In each case, a controller is needed, typically costing $1000 and taking up to four drives. The capacity of a disk may be increased by using double density and recording on both sides. With a dual floppy disk unit, recording at double density on both sides of the disk, it is possible to obtain one million bytes of memory. Super capacity disks are already available, packing almost one million bytes onto a five and one quarter inch disk; and it is possible that, with improved plastic, up to five million bytes could be recorded on an eight inch disk.

Floppy disks are now being challenged, however, by hard top disks. The Winchester type hard top disk, generally 14 inches in diameter, is a standard type of magnetic disk on a large mainframe. The high reliability technology used for these disks is now being applied to smaller disks, generally eight inches in diameter. In 1979, only International Memories Inc. had such a disk in production, priced in single units at $3000 U.S. and holding 11 million bytes. By the end of the first quarter of 1980 it is anticipated that at least 12 manufacturers will have such disks in production, at single unit prices between $1900 and $4000 and holding between two million and 51 million bytes. Forecasts are that within one year these prices will be reduced to one third of the present levels.

Extrapolating, it would appear that floppy disks will be used for memories of up to approximately five million bytes, eight inch hard top disks for memories between approximately five and 20 million bytes, and 14 inch hard top disks for memories above 20 million bytes.

However, technological developments in this area are particularly difficult to forecast. The only assurance is that costs of disk storage may be expected to come down further.

For example, one floppy disk manufacturer, Shugart, is expected to deliver a five inch floppy disk made by Matsushita for $70; and Texas Instruments is developing a small Winchester type disk drive to sell for approximately $50.

To put together a working microcomputer it is at present customary to assemble the necessary components onto boards. One standard size is 10 inches by 5 inches, for boards which may be easily slotted into a connecting base known as the "S-100 bus". Separate boards are used for the central processing unit, RAM, EPROM, character and graphics generators, input/output controls, synthetic speech, and other functions. Again, however, the position is changing rapidly. Each board is being reduced to one chip, and chips are being developed which combine the functions of two or three boards. Rockwell, for example, has introduced a single chip which holds an 8-bit central processing unit, 2048 bytes of ROM, 64 bytes of RAM, 32 input/output lines, and a 16-bit timer-counter. INTEL is producing one chip with an 8-bit central processing unit, 2048 bytes of ROM, 128 bytes of RAM, over 20 input/output lines, and a two channel analog-to-digital converter.

It is projected that by 1985, possibly earlier, there will be available on one chip a 32-bit central processing unit and a quarter of a million bytes of memory, requiring power from no more than a five volt battery. It appears that the hand-held computer will be as powerful as the present mini-computer.

Obviously, computing power is becoming cheaper and software is accounting for more of the total systems development costs. In 1975, software accounted for 50% of the total; in 1980 it is expected to account for over 90%. The people who use the machines will be far the most expensive part of the total operation. True, machines will become "friendlier" and easier to use, and this will help to keep down the "people" cost. However, when a computer is used for CAI, there is the additional cost of the teaching programs, the courseware: this again is a "people" cost.

Oddly, the development of technology emphasizes the value and importance of the person who uses it.

Development of Microcomputers

The availability of silicon chips is a necessary but not a sufficient condition for the development of a microcomputer. As indicated above, the appropriate chips must be assembled, generally on boards, and interfaced to supply all the necessary hardware functions of the microcomputer; and a power supply must be added. The whole must then be provided with a software system, for which it is also necessary to provide terminal handlers, and preferably at least one high level language.

The development time required to produce such a microcomputer meant that the first did not appear until January 1975. This was the Altair 8800, which was produced in kit form. During 1975 and 1976 most microcomputers were sold in this form, as hobby computers, intended for people having some prior knowledge of engineering and computing. Such microcomputers were obviously not appropriate for most educators.

However, in April 1977 Commodore announced the PET 2001 microcomputer, a fully operational turnkey package, designed not for the hobbyist but for the general consumer. This represented a dramatic change: it was the first microcomputer that had immediate appeal to the educator. Within a year, PETs had been purchased by a large number of schools in the U.S., and were a topic of discussion at the annual meeting of the Association for Educational Data Systems.

In July of the same year, Radio Shack introduced a competitor, the TRS-80 microcomputer, and others have since followed in rapid succession. These include such machines as the APPLE, IMSAI, Exidy Sorcerer, COMPUCOLOR, Ohio Scientific: it is not possible to mention all that are now available. Further, microcomputers first produced in 1977 and 1978 were mostly available, by 1979, as a much improved second generation.

Total sales by the end of 1979 included more than 100,000 TRS-80s, 80,000 APPLEs, 30,000 PETs, and 10,000 COMPUCOLORs. Moreover, sales are growing rapidly at prices from $750 upwards. An interesting reflection is that many of these microcomputers already have the same power as many university computers of 15 years ago, with much better reliability. Further, this has been accomplished by using 8-bit processors. Microcomputers are already available which use a 16-bit microprocessor, but there has not yet been time for the industry to take full advantage of these more powerful processors.

The peripheral devices available on microcomputers have expanded rapidly. Character and graphics generators for color monitors are quite common, as also are joystick controls. Synthetic speech is less common but is available, and limited speech recognition is also obtainable. Keyboards can have separate number pads and various inexpensive printers are in production, some having limited graphics capability. Moreover, all such facilities can be purchased at quite reasonable cost. A printer, for example, can be obtained for $500.

Attention should be drawn to those microcomputers which use a particular bus, or system of interconnecting the various boards, known as the standard one hundred-line bus, or the S-100 bus, which was referred to earlier. Microcomputers using this standard are available from several manufacturers. Alternatively, it is possible to purchase a cabinet built around an S-100 bus taking up to 20 or more boards. The various boards needed for any specific computer configuration may then be purchased from any of a large number of manufacturers, and may be slotted into the cabinet with no difficulty. In effect, it is possible to assemble a microcomputer tailored to one's own needs and, as those needs change, to modify the microcomputer accordingly. In 1978 alone almost 100,000 S-100 systems were manufactured, and it is possible that this system is now more widespread than any other type of computer system.

An almost universal high level language on microcomputers in BASIC. This was often available initially in a somewhat restricted version only, but extended BASIC is now being provided for most machines. For use in CAI, it is important to have a version which provides character handling, string variables, an efficient file system and, preferably, chaining of programs. In the future, it is possible that PASCAL will become an important high level language: already it is used as the assembler language on Western Digital's 16-bit microcomputer. Also, it is anticipated that the NRC language, NATAL-74, will become available on a microcomputer delivery system: as mentioned earlier, work is already in progress to develop such a system. Various other high level languages are available on specific machines. For example, the Exidy Sorcerer supports APL.

The market which has been created for microcomputers has produced a need for information about them. Numerous publications devoted to microcomputers have appeared, such as *Byte*, *Dr. Dobb's Journal*, *Interface Age*, *Kilobaud Microcomputing*, *onComputing*, and *Personal Computing*. Some older journals such as *Creative Computing* devote sections to microcomputers; and there are now journals devoted to one particular microcomputer, such as *APPLE*, and *80 MICROCOMPUTING* (for the TRS-80). Computer stores were greeted with surprise three years ago, but are now part of the commercial scene. Computer clubs have substantial memberships (e.g. over 20,000) in some parts of the U.S., and Personal Computer Conferences and Computer Fairs attract a large attendance.

Use of Microcomputers for CAI

Microcomputers as Stand-Alones

The presence of microcomputers in schools makes certain forms of CAI practicable, and is producing an increasing interest among teachers in the use of computers for instructional purposes.

However, the variety of microcomputers now available presents a difficulty to the educator who wishes to purchase one. Some school boards, notably in the State of Minnesota, have therefore conducted a detailed analysis of selected systems. On this basis, the Minnesota Educational Computing Consortium (MECC) has in two successive years drawn up specifications which could be used in an invitation to manufacturers to bid for the supply of microcomputers to the participating school boards. For the first year, 1978-79, the minimum number of computers was set at 100; in the event, the schools and colleges purchased over 1000.

In Minnesota, as in other states in the U.S., microcomputers are used in the schools for the teaching of computer literacy and computer languages. They are also used for CAI, including problem solving, simulations, drill and practice and tutorial programs. It is considered that they are more effective than general time-sharing computers for drill and practice, tutorial programs, and the teaching of programming; whilst there is at present no evidence regarding problem solving and simulations.

Most programs are developed and shared locally. Although the situation could change in the future, few CAI programs are available commercially, and those few are of doubtful quality. The MECC 1979-80 report declares: "A major concern of educators who purchase a microcomputer is the availability of applications software". In Alberta, the acquisition of microcomputers by schools started later, but already the same concerns are evident in this Province in those schools which now possess one.

Unless steps are taken to resolve this problem, there is a real danger that microcomputers will be purchased by schools and, shortly, relegated to a cupboard for most of the time. The danger is especially acute where CAI is concerned: unless sufficient high quality programs are available, there is no possibility that a microcomputer can be used sufficiently to justify its cost.

When acquiring a microcomputer for CAI, certain other considerations must also be kept in mind. Some earlier machines had a keyboard too small for continuous use, and others had too small a CRT display. These particular difficulties have now been overcome and most, although not all, microcomputers have well formed and easily readable character displays. Some also have color, and graphics, although the latter generally lacks the definition that will be needed in the future for certain forms of CAI.

However, there are still problems relating to the number of lines and the number of characters per line. Twenty-four lines of 80 characters has become customary on standard CRT terminals. Apart from those using the S-100 bus, few microcomputers offer so many characters per line. It is likely that 20 lines of 40 characters will be adequate for most CAI programs; but it appears questionable whether 16 lines of 32 characters will be sufficient at high school level.

Some microcomputers do not have lower case characters, which may be needed for reading and spelling programs. For some purposes, as for example for CAI with the handicapped, large characters may also be required. Few microcomputers have the facility to create special characters, which are desirable for foreign languages, mathematics and statistics.

Most microcomputers can now take a sufficient amount of electronic memory to run large programs, and have available a floppy disk. As auxiliary storage, the latter is essential: cassette storage is often unreliable, and is much too slow for CAI. Also, with an optional control, most can now take a printer, which is necessary when writing a large CAI program. Some microcomputers, notably the COMPUCOLOR, come in one compact cabinet, a feature which will recommend itself to many teachers.

However, when a number of stand-alone microcomputers are used for CAI a serious problem arises in relation to record keeping. Small programs may frequently be used without any attempt to keep a record of results. On the other hand, with a CAI program of any size, student records are necessary for a variety of reasons: to permit continuous evaluation and improvement of the program; to route each student, over a period of days or weeks, through those topics which he needs to study and through any remediation which is required; and to remove the burden of record keeping, testing, and marking from the instructor. A centralized record keeping system is essential, at least for all students taking a CAI program with the same instructor. There is often no necessity for the records to be kept outside the school, or even outside a particular classroom; but responses made at all the separate microcomputers within one classroom should be recorded in one record keeping system, and it might well be desirable to keep records on a wider basis.

For effective CAI, stand-alone microcomputers are not sufficient. They must be linked to a central processor with a substantial amount of storage.

Microcomputers as Terminals

One solution to this problem is to make the microcomputer into an intelligent terminal, and to attach it to a large computer in which records are kept.

Essentially, this is a solution adopted in the Faculty of Education Computer Applications Unit at the University of Calgary. A microcomputer was developed around an S-100 bus, and was designed so that it became a terminal to a DEC 11/70 computer. Fifteen such microcomputers now serve as multi-media terminals, with all programs and all records being stored on the 11/70 computer. However, with the addition of extra memory, the same microcomputer can act as a terminal or as a stand-alone computer system, changing from one mode to the other as commanded by a message from its keyboard.

Most of the more popular microcomputers now have available an option which allows them to be attached to another computer. Essentially, this consists of an "RS-232" or "IEEE" port which accepts a connector for a standard communications cable, and the necessary internal control software. However, this in no way ensures that the microcomputer can immediately "talk" to its host. A considerable amount of software must also be developed, which varies with the type of microcomputer, the particular host computer, and the facilities required. It may be desired, for example, to down-load programs from the host computer to the microcomputer, and then to use the latter as a stand-alone system.

Down-loading of programs from a host to a microcomputer became fairly common during 1979. It has been done from the central MECC computer to the APPLEs purchased by the schools in Minnesota; from the Phoenix Data CDC computer to TRS-80 microcomputers located in schools associated with the CAI project at the University of Manitoba; and from the AMDAHL computer to the TRS-80 microcomputers used by the CAI project at the University of Alberta.

The cost/benefit of down-loading requires careful consideration. An alternative is to distribute floppy disks containing the necessary programs. This is the procedure used when sending programs from the CAI project at the University of Calgary to a stand-alone microcomputer in Banff. However, in an environment where a large number of microcomputers are attached to one host computer, where a large number of programs are being developed quite quickly, and where all users require a different selection of available programs, down-loading may be the best route to take. This is especially the case where distances and communications costs are not too high.

However, down-loading does not solve the problem of centralized record keeping. This demands either that, when a CAI program has been used on a stand-alone, the response record is read back to the host computer to update files kept on the host; or, that the microcomputer is used as a terminal, with all student responses being recorded in a file on the host. In either case, if the microcomputer is far removed from the host, communications costs become high and must be weighed against the costs of setting up a local host computer.

An example may illustrate the problem. A proposal was made to use a CAI terminal in Banff, connected to a DEC 11/70 computer in the Faculty of Education at the University of Calgary. The cost of renting one telephone line for the purpose was, in one year, approximately equal to the cost of purchasing a microcomputer. The solution was to set up the stand-alone microcomputer at Banff, referred to above, to be connected into a local host when justified by demand.

The relatively lower costs of computer hardware, as compared to communications costs, suggest the need to examine the possibility of setting up a local host computer for CAI, with terminals attached not through a telephone line but hardwired by direct connection with the computer. Such CAI terminals may be "dumb" or, preferably, "intelligent". The intelligent terminals will probably be based on some form of microcomputer.

The low cost of microprocessors, and their increasing power, is leading to their use throughout a CAI system, in terminals and displays, in keyboards, and in a variety of peripheral devices. A powerful and inexpensive CRT terminal, for example, can be made from a microprocessor and no more than five other chips. A microcomputer terminal, assisted by its own microprocessor devices, can itself take over some of the functions otherwise performed by the host computer. In effect, it can become part of a powerful distributed processing system, in which the host no longer has to be a large, expensive mainframe.

Such a system has been designed and is now being developed by the National Research Council of Canada, to operate the CAI language NATAL-74.

One question to be determined is whether a microcomputer could act as a host for a CAI system.

Microcomputers and Multi-User Systems

A typical time-sharing system in the past has been centred around one central processing unit, and has used software to share the time of this unit among a number of terminals which had no processing capability of their own. When such a system has been dedicated to CAI it has worked well, and all major CAI projects have had a dedicated machine. Problems have very frequently arisen when some terminals have been used for purposes other than CAI. When they have been used for statistics or number crunching problems, for example, this has frequently led to an unacceptable deterioration in response time. Similar problems have arisen when attempts have been made to mix CAI with batch processing, and when the time slice provided to each terminal has been increased so that, again, response time has suffered. Further, CAI mixed with administrative applications on the same computer has invariably suffered at times of peak demand for such applications.

This discussion therefore concerns a computer dedicated to CAI, which will provide to each terminal a response time of not more than one second, and preferably much less. Also, it is assumed that a minimum amount of computer storage is required, estimated approximately from the number of ports available for the connection of terminals. Storage of one million bytes per port is more than adequate for most CAI. Some would regard this amount as excessive, and consider 150,000 bytes per port to be sufficient. Much depends upon the environment in which the system is operating: in some cases extensive records may be required, in other cases none.

However, the discussion no longer concerns a typical time-sharing system. Rather, it relates to a "distributed processing system". The term is used to describe a variety of configurations, ranging from the use of multiple processors within one computer, to the use of multiple computers within a network. In the present context the concern is with the use of a distributed processing system within one school or one institution, having a central computer which keeps common files and possibly performs some other processing, and from two to 32 (or more) hardwired intelligent terminals, each of which might be a microcomputer with its own file storage. Such a system might be described as a "shared resource system". The central computer itself might contain several microprocessors, each performing a specific function. The terminals might also each contain several microprocessors to control communications with the central computer, drive the character display and graphics, provide flexibility in the keyboard, or control a disk. A mass memory device, such as a large disk, attached to the central computer would form a shared resource.

It has been shown earlier that inexpensive hardware is already available, or soon will be, to perform all of these functions. The question is, when will the software systems be available?

The reason for this question can readily be appreciated when we consider the figures quoted in the discussion of microprocessors and memories: in 1980 it is anticipated that software will account for 90% of the cost of developing a computer system. Only very large CAI projects, such as the PLATO project, or projects concerned with the development of hardware and software rather than courseware, such as the Canadian NRC project, can afford the costs and resources necessary to develop special purpose software systems.

Other projects are better advised to make use of a standard software system offered by a manufacturer or by a software house.

Several systems are already offered which are based upon a microcomputer. For a number of years, Digital Equipment Corporation has offered an LSI/11 based upon a 16-bit chip set developed by Western Digital. A new and improved version, the LSI/23, using a 20 million byte disk, costs between $25,000 and $30,000, and will support up to eight terminals simultaneously.

A similar 16-bit chip set is used by Alpha Microsystems to provide a two user system for approximately $20,000 U.S.

CROMEMCO has developed a seven user system based upon the Z-80, an 8-bit microprocessor. Using a ten million byte disk, this system costs approximately $18,000 U.S.; using instead dual double-sided floppy disks, providing two million bytes, it costs approximately $12,000 U.S. Whereas initially it provided BASIC only, the system now also provides FORTRAN and COBOL.

Other systems using an 8-bit chip are the Altair and the North Star. The latter uses a 20 million byte disk for a five user system costing approximately $15,000 U.S., and may be configured more cheaply using floppy disks.

Late in 1979, Ohio Scientific announced an 8-bit microprocessor based system having both distributed processing and networking capabilities. Microprocessors with floppy disks act as stand-alone computers, and use a central data base for disk storage, printer output and other shared resources. The total is referred to as a "cluster". In large applications, several clusters may be interconnected as a network. Each central data base uses a Winchester disk, and will support up to 16 intelligent terminals and up to 16 dumb terminals. Of particular interest is the fact that complete systems may be built up gradually, starting from one microcomputer.

Also available in late 1979 was a multi-user system for the 8080 and Z-80 microprocessors, produced by the Computer Systems Design Group. An interesting feature of this system was the fact that it was modelled upon the UNIX system, a time-sharing system developed by Bell Labs for DEC PDP 11 computers, which has been very popular in educational institutions.

Early in 1980 Altos Computer Systems announced a four user system based upon a Z80 microprocessor and using a 58 million byte Winchester disk, at a price of under $12,000 U.S. A 20 million byte Winchester disk system, based upon the use of a separate Z80 for each of four users, was produced by Micromation.

A low cost system, Cluster/One, was announced by Nestar Systems early in 1979. This allowed stored information, in the form of programs or data, to be shared by a number of microcomputers. It consisted of a central microprocessor unit with floppy disks having from 630,000 to 1,200,000 bytes. To this could be attached up to 15 or 30 microcomputers, which could be PETs, APPLE IIs, or TRS-80s. The cost of the central unit began at $5000 U.S. The system therefore provided low-cost hardware and software which was easy for students to use. However, it did not allow the creation on the central disk of data files accessible to selected users only, and would not therefore support a CAI system with record keeping facilities.

In early 1980, however, a second generation system, Cluster/One "Model A", was produced. Using an Apple microcomputer with 48,000 bytes of memory as a central controller and either a floppy or Winchester disk system to hold files, this can link from two to 65 standard Apple microcomputers into a network. Communication cards are required for the control Apple and for each user Apple; and the latter must be within 1000 feet of the control Apple. Shared files on the central disk system may be accessed by the controller. The hard disk system, with 33 million bytes of memory, costs approximately $10,000 U.S.

A significant feature of all the present multi-user systems based upon microprocessors is that they do not yet make use of the new and powerful 16-bit microprocessors such as the INTEL 8086 or the Motorola 68000. Sixteen bit microprocessors and hard top disks are needed so that a larger number of terminals can be supported whilst retaining fast response time, and so that unit costs may be reduced whilst still retaining the facilities of a traditional time-sharing operation.

Obviously, multi-user systems based on 16-bit microprocessors are coming, and a software house has already committed itself to the production of the necessary operating system. Digital Research originated the CP/M operating system, which has effectively become an industry standard and is the most widely used software system for microprocessors. In mid-1979 the company announced MP/M, a multi-programming system for the 8080 and Z-80 8-bit microprocessors, upon which the CROMEMCO, Altos, and Micromation multi-user systems are based. Digital Research has now indicated that a comparable system, MP/M2 for the INTEL 8086 and Z8000 16-bit microprocessors, will be released at the end of the third quarter of 1980. When this system is implemented by microcomputer companies, with terminal handlers and using a hard top disk, it may be expected to provide the basis for a powerful and low-cost multi-user microcomputer system.

Such a system will also soon have the benefit of new hardware devices. All the 16-bit microprocessor manufacturers are introducing integrated circuits which will permit their microprocessors to perform operations until now restricted to mini-computers and large main frames. These include units allowing the microprocessor to partition and manage its memory; and units allowing it to manage the bus, so that more than one microprocessor may be on the bus at one time.

The MOTOROLA 68000 microprocessor is being built into a multi-user system by the World Institute for Computer Assisted Teaching (WICAT) of Utah. The design calls for a "storage station" incorporating an MC 68000, 128,000 bytes of RAM, and a 50 million byte Winchester disk controlled by a second MC 68000. Operating as a stand-alone microcomputer, it is estimated that the storage station could support up to 100 on-site "work stations", which could be either dumb terminals or small microcomputers such as the APPLE or ATARI, with down-loading and up-loading as required. If necessary, it would also be possible to link the "storage station" to another remote computer.

More powerful "work stations" are also designed for on-site use with a storage station. Each of these would use an MC 68000 microprocessor, 128,000 bytes of RAM and, where needed, a videodisc under computer control. Such stations would provide not only a very powerful tool for advanced students, but also multi-media CAI for students and subject areas requiring such facilities. Since the storage station and the more powerful work station would be modular, costs would be minimized.

The estimated cost of a storage station is $15,000 U.S., and of the more powerful work station $4000 U.S. if attached to a storage station, or $6000 U.S. if used as a stand-alone with a floppy disk. Initial deliveries are scheduled for the end of 1980, with the basic work station system aimed at the public school market and the more powerful work station system aimed at the college and commercial market.

An interesting feature of the design is that it aims to produce a "final configuration". The assumption is made that the present rapid technological change in CAI systems will eventually come to a close, with a central storage station and work stations using powerful but inexpensive microprocessors and large quantities of inexpensive memory. Looking forward to a very low hardware cost for such a system by 1985, the design calls for a first implementation in 1980.

Meanwhile, in early 1980, INTEL released information of three 32-bit microprocessors. One, designated the P5 Micro-Mainframe, will have no assembly language and will directly execute the high level language ADA, a super-set of PASCAL. It consists of three chips: a processor, a storage module, and a bus interface; and up to eight processor modules may be placed together on the one bus if greater processing power is required. The P5 is due to be distributed in late 1980. The other two 32-bit microprocessors will not be available until late 1981, and will use a super-set of the 8086 16-bit microprocessor code. However, the P1 will execute code 1.3 times as fast as the 8086, and the P2 three times as fast. Both will be capable of directly addresing 16 million bytes of memory, and will virtually address one gigabyte of memory (i.e. one thousand million bytes). The P2 is designed specifically for multi-user operations.

It is now clear that by 1981, 16-bit microprocessor systems will become commonplace and that they will have powerful multi-user capabilities. It is also clear that they will be followed within two years by 32-bit microprocessor systems. Both will provide a basis for inexpensive CAI applications in schools.

Hard Copy and Display Terminals for CAI

For many years the Teletype, in the form of the KSR 33, has been the work-horse of CAI. It was used, for example, for the early Stanford and CCC work, and has played its part in most Canadian projects. This is despite the fact that it is slow and noisy, has a comparatively short life, and is expensive to maintain. In later years it has been supplemented by other hard copy terminals, which have had the same disadvantages to a less degree, and which intially were much more expensive. Having more mechanical parts, all hard copy terminals have tended to be less reliable than display type terminals.

Cathode ray tube terminals were used in the IBM 1500 system from the beginning, but like early CRT's in the German CAI projects, did not have their own refresh facility. Since they were refreshed from the main central processing unit, they had necessarily to be placed within a very limited distance (e.g. 1000 feet) from the computer. For many applications this was a very serious disadvantage. Knutson and Prochnow (1970) found in a CAI project for the handicapped that students spent more time on travel to and from the computer laboratory than on interacting with the CAI materials.

CRT's with their own refresh facility appeared in the early 1970's. At first they were quite expensive, but have rapidly become cheaper and more intelligent. They have several advantages over hardcopy terminals. It is possible to write on the screen at high speed, selectively erase part of the writing such as a wrong answer and if necessary rewrite it in a different location on the screen, position the cursor at any place on the screen where the student is required to give an answer, and use reverse video to highlight part of the message and a blink feature to attract the student's attention. A display type terminal is very useful when the courseware author wishes to clear the screen, present one or more remedial sequences, and then return to the same point in the main program. Sometimes a terminal provides graphic facilities and features which allow the student to position the cursor.

It is now apparent that display type terminals will be generally used for CAI in the future. However, it must be noted that they should have full cursor control, and preferably most of the other features referred to above. Also, for many purposes they should have special characters such as French accented characters, mathematical and scientific symbols, and subscripts and superscripts. In some cases, there will be a need for still further special characters such as, for example, Bliss symbols for use with the handicapped.

Some terminals now incorporate a second character set, which may be programmable by the user. At the present time, however, the programming requires preparation of an EPROM chip, a task which will not be practicable for most users.

Terminals are acquiring progressively more intelligence, and attention has already been drawn to the use of microcomputers as terminals. These provide more facilities and greater flexibility than other display type terminals but, although sometimes no more expensive than a CRT terminal, they have certain disadvantages as indicated earlier. In particular, it has been noted that the standard for CRT terminals, 24 lines of 80 characters, is generally not met by microcomputers.

In the PLATO project, display type terminals have been used from the beginning. However, these are plasma terminals, as described in the discussion of the PLATO project. A particularly attractive feature is their graphics capability. This has allowed the development of CAI programs which, until recently, could not possibly be produced elsewhere. Such programs have demonstrated what CAI could become, given better terminal facilities.

Several years ago it appeared that the plasma display would become the basis for most CAI terminals. At present, this no longer appears to be the case: costs of CRT displays have been reduced, whilst costs of plasma displays have not; and the facilities formerly available only on plasma displays are now available on intelligent CRT terminals.

Plasma displays are slowly becoming available from a number of sources, and could become more generally used at some time in the future.

It is now apparent, however, that the immediate future of CAI lies with intelligent CRT's or microcomputers, frequently serving as the basis of multi-media CAI terminals.

Multi-Media Terminals for CAI

The Need

It has already been indicated in the discussion of CAI projects that, with many students and for many subject areas, the use of other equipment besides a hard copy or display terminal is very desirable; in some cases it is essential.

If handicapped students are to be taught money handling and shopping skills by CAI, it is necessary to have images of money and items to be purchased, displayed on a screen. For many such students, simple audio messages are required because they are unable to read; and audio output is obviously needed to teach many aspects of reading and foreign languages. In mathematics, a more extensive use of graphics could improve much of the present CAI. In science, simulations using graphics and images could help prepare students for laboratory work. In some cases, they could allow students to simulate experiments which are not possible in the laboratory for reasons of expense, safety, or praticality. Use of color could make CAI more attractive to a generation brought up on television.

CAI Terminal Design

Multi-media CAI terminals have been in use for a considerable time in some projects.

The IBM 1500 system, in particular, has always made use of a CRT display, image projection, audio output, and a lightpen. The PLATO system has used the plasma display, image projection, audio output, and a touch sensitive panel. In both cases, control of the peripherals at a terminal has been performed directly by the central computer, through local switching devices at the terminal. Also, each system uses its own tailor-made operating software, which requires that its unique type of terminal be used if multi-media facilities are to be made available to the student.

The CAI project at the Canadian National Research Council has undertaken work on multi-media terminals which, over a period of years, has kept it in the forefront of such developments. A different approach has been taken from that used in the IBM 1500 and PLATO systems. The assumption was made that CAI users need a variety of terminals tailored to specific requirements, therefore multi-media terminals should be modular. Further, they should be capable of attachment to any computer system using ASCII code. This makes it possible for a CAI project to use a commercially available time-sharing system, and to incorporate a variety of terminals and terminal configurations as required. However, it also implies that, since the multi-media terminal must appear to the time-sharing system as the single ASCII-type terminal it expects, an interface must always be provided between such a terminal and the communication line to the computer. A series of such interfaces has been produced.

The first NRC prototype station was developed in the early 1970's. It employed an electronic interface which made it possible to use a hardcopy or CRT terminal, image projection, audio output and a touch sensitive display. After very successful use at a number of locations in Canada, it was followed by a commercial version of the same apparatus. This used a small central processing unit to act as the interface and to control all the station devices.

In the late 1970's, however, it was difficult to find, commercially, a multi-media terminal which was reliable, flexible and inexpensive. Faced with such problems, the NRC developed other terminals based upon a microprocessor. The PLATO project also produced the microprocessor based PLATO V terminal, capable of supporting a variety of peripherals. At the University of Calgary a multi-media terminal was needed for CAI with the handicapped and it was found necessary to develop one within the project. The resulting terminal is based upon an S-100 bus and an 8080 microprocessor, and offers considerable flexibility. It supports a CRT or hardcopy terminal, image projection, audio output, a lightpen, and a variety of other input devices.

An account has already been given of numerous microcomputers now on the market which can be configured as multi-media terminals. Smaller, cheaper and more powerful microcomputers are about to become available, with greater capabilities for the attachment of a variety of peripheral devices. Some will provide an excellent basis for a multi-media CAI terminal, and such terminals will become readily available. Moreover, they will change the nature of CAI programs.

Few programs have yet been produced which make full use of such facilities. The cardiology program at the University of Alberta is a notable exception. Programs for junior high school mathematics and science simulations on the PLATO system, and programs for the handicapped at the University of Calgary, have begun to make successful use of graphics or image projection. In the near future, multi-media facilities could become available to many CAI projects. But there will be little courseware to make use of them.

It is therefore important to consider what specific facilities are likely to be available.

Image Projection

For image projection the PLATO terminals make use of microfiche controlled by a compressed air device. The IBM 1500 terminals use film strip. Both of these media can have black and white images, and color.

In the late 1960's numerous projects attempted to use a variety of 35 mm. slide projectors, but few of these terminal interfaces worked reliably. The NRC and Calgary projects interfaced the Kodak random access carousel slide projector and have now used it successfully for some ten years. Interestingly, the CDC PLATO system has abandoned microfiche and now uses the same Kodak projector. The equipment has good reliability, and offers flexibility in that slide sequences can be repeatedly changed as a program is developed. The slides are easy to produce, and provide images of much higher quality than microfiche. Disadvantages are that the equipment is expensive, at $1000 per projector; and one carousel tray holds only 80 slides.

No CAI project has yet made extensive or regular use of moving film sequences under computer control. Further, the technology used for the projection of still images, although reasonably effective, is ten years old and could now be substantially improved upon. New and impending developments are therefore considered later.

Audio Output and Voice Recognition

In all multi-media CAI stations, the weakest element has been audio output. This has been unreliable, or slow, or poor in quality, or small in quantity, or all of these.

The IBM 1500 terminal uses an audio tape player which is comparatively successful; however, it is very expensive to maintain. The PLATO terminal uses a disk controlled by a compressed air device. This is comparatively easy to operate and small children can load a new disk. However, it is again expensive to maintain and even at a center within three miles of the PLATO project the audio devices are frequently out of use due to breakdown of the apparatus. It is of interest to note that the CDC PLATO system does not attempt to use audio.

At the NRC project the first multi-media terminal used a tape recorder and later commercial versions have used a cassette recorder. The same unreliability has been experienced. However, another important disadvantage is the slow access of messages on a medium which is essentially sequential. Even with careful programming this is the slowest terminal device. Except where audio is essential and no other audio source is available, a cassette device should probably not be used at all. At the present time, there is therefore a movement towards the development of synthetic speech devices.

In order to produce "fully digitized" or "synthetic" speech, digitized data representing the speech are encoded and stored in computer memory, and are later transferred to an output device which reconstructs the words and phrases. The encoding procedure determines the amount of data needed to represent speech, and therefore the amount of memory required and the data rate which much be used for transmission from the memory to the output device.

One procedure is to code the wave form of the speech, by any one of a number of possible coding methods. This produces what is sometimes referred to as "fully digitized speech". The Stanford project experimented with it before 1970, the messages being stored on a large IBM magnetic disk. At the present time it can be used, on a very small scale, on the APPLE II microcomputer. Excellent reproduction can be obtained, but a large amount of storage is required for even a short message and a high data rate must be available from the storage medium to the output device. For quality speech the data rate varies, according to the encoding procedure used, from 16,000 bits per second up to 64,000 bits per second and more. This may be compared to 9,600 bits per second to drive a very fast CRT on which a page of characters is perceived to appear instantaneously. At the lowest speed, a ten second message requires the equivalent of 20,000 bytes, which at present densities would require ten EPROM chips for storage. One side of a single density eight inch floppy disk would hold just over one minute of speech, and would require electronic memory into which messages could be read before being passed to the output device. In effect, fully digitized speech may be employed for a few short messages, but will not represent a solution to the problem of producing audio until mass storage and fast memory are much cheaper, and more powerful microprocessors are in use.

A second procedure for producing synthetic speech is to describe the speech by a system of phonetics, using an encoding system which represents each phonetic symbol, and to develop a synthesizer which makes use of the same phonetic system. This is the procedure upon which the Votrax voice synthesizers are based. With careful phonetic coding of the required speech the procedure can result in very good reproduction. Moreover, it produces a substantial reduction in the amount of memory needed, and in the data transfer rate required from the memory to the synthesizer. The latter, for example, may be as low as 300 bits per second, which is the speed of present hard copy terminals, and even lower speeds down to 80 bits per second are possible. Problems lie in the price of the Votrax: at approximately $3000 for a unit which will produce acceptable messages for a CAI program, the cost is too high to justify its employment except in special circumstances. Another restriction is that the phonetic system necessarily imposes limits upon the range of speech which may be reproduced. Earlier units, for example, would only reproduce a male North American voice speaking in English. Although such limits may be extended, the procedure is inherently less flexible than other synthetic speech procedures.

The Votrax has been used experimentally in the NRC project with considerable success. Pre-coded messages are reproduced clearly. Programs have also been developed which accept a message typed in English, encode it phonetically, and transmit it to the Votrax for immediate reproduction as speech. In the PLATO project at Illinois, experimental use of the Votrax has led to the development of programs which will accept typed sentences using World English Spelling, and transform them into Votrax speech with a correct intonation pattern for the sentence. This is most easily effected in Esparanto, but is also possible in English and Spanish.

A third procedure for the production of synthetic speech is to define the formants of speech, and to devise a synthesizer to produce these. An early example of such a synthesizer is the Parametric Artificial Talker developed by Walter Lawrence as a vacuum tube machine, and later produced in a transistor version by the University of Essex in the England. A present example is the Computalker, which employs eight formants of speech. This is used on an S-100 bus card in the University of Calgary multi-media terminal, and is available as a peripheral to the APPLE II microcomputer. Again, the procedure effects a considerable reduction in storage requirements and in the data transmission rate. However, the reduction is not as great as with the Votrax: the Computalker requires approximately 7,200 bits per second. A phonetic system is available for the Computalker, so that words and phrases may be coded, read into the computer, and transformed into assembler code which is stored in EPROMs for later use. A reasonable quality of speech may be obtained at quite low cost: for both the S-100 bus and the APPLE II, a Computalker costs approximately $400 U.S.

Recently, a fourth procedure for the production of synthetic speech has attracted increasing interest. This is linear predictive coding, which can produce high quality speech with a data rate of less than 2,400 bits per second. In practice, an effective data rate of 1,500 bits per second is feasible. As implemented by Texas Instruments in a small electronic learning aid known as the Speak and Spell, the procedure uses three inexpensive silicon chips: a ROM chip, a controller chip, and a speech synthesizer chip. Speech data in the ROM are coded to indicate pitch and voiced and unvoiced sounds, which determine whether random or periodic data will be supplied to a filter; to indicate amplitude, which determines the required volume of the output signal; and to indicate the number of times data must be passed to the filter on the synthesizer chip. The vocal chords are simulated by an excitation signal, which is modified to the required amplitude, and by the filter, which in effect simulates a constantly changing vocal tract. The output signal is passed through a digital-to-analog converter which produces the synthesized speech waveforms, and then is connected to a speaker. Such chips may well represent the most effective form of synthetic speech which will be available in the near future.

A voice recognition device, the Huristics Speech Laboratory, is available for the S-100 bus and for the APPLE II microcomputer, but has so far been little used. It may be effective for recognizing a few simple commands, such as "Yes" or "No". However, it must be provided with data relating to the voice of each user. This poses problems which, at the present time, seem to imply that it is not an appropriate input device for CAI except in special circumstances.

Graphics, Color and Animation

Until recently, the only CAI projects able to make extensive use of graphics were the PLATO and TICCIT projects. In both cases, the graphics have been a great attraction to the learner.

The plasma display used in the PLATO project allows control of 512 x 512 points and, with suitable commands in the TUTOR language, makes the production of graphics relatively easy. The programs for elementary school mathematics, which were described earlier, use the graphics capabilities of the system to provide a variety of attractive and very effective learning sequences not yet seen in any other CAI project. The same can be said for the science simulations. Such graphics can be either pre-stored or generated, and use orange on black only.

In the TICCIT system, graphics using color can be pre-stored. The authoring system may be linked with photographic equipment which copies photographs or drawings either in part or as a whole, expanding or contracting the image as required. The facilities are relatively easy to use and the result is that TICCIT programs make far greater use of graphics than do programs in any other project except PLATO.

The physics computer development project at the University of California in Irvine has explored the use of graphics at undergraduate level in an attempt to develop "effective visual dialogs" (Bork, 1975).

Until recently, use of graphics was too expensive for most CAI projects. With the appearance of microcomputers, however, the situation has changed and a more widespread use of graphics is now possible. In

1976, NRC used an Altair computer to achieve control of 512 x 512 points (pixels) on a CRT monitor, demonstrating that the type of graphics used in the PLATO system had become quite feasible using a CRT display. The University of Calgary multi-media terminal uses an S-100 bus card produced by Matrox, of Montreal, giving a definition of 256 x 240 pixels; and other Matrox cards give a 512 x 512 definition. Most microcomputers have graphics, but generally these are "character graphics" with lower definition: the APPLE II offers 24 x 40, the PET 25 x 40, and the COMPUCOLOR 32 x 64. However, the COMPUCOLOR also offers control of 128 x 128 pixels and, in a more expensive version, 256 x 256 pixels.

It may be expected that, as microcomputers develop, better definition will become available and more authors will make more extensive use of graphics. However, it will also be necessary to determine in what subject areas graphics are in fact useful, and with which learners. Graphics could easily be over-used, and merely confuse the learner (Moore and Nawrocki, 1976).

The same may be said with regard to the use of color. Except in the TICCIT project, this has not been available on CRT displays until the advent of microcomputers. It is a standard feature of the COMPUCOLOR, is available for the APPLE, and can be readily produced on the S-100 bus by the use of extra Matrox cards. There is no doubt at all that color is a very attractive feature, and that in many programs it is useful. However, much has to be learned regarding when and how to use it: some early programs using color are merely confusing.

Animation has not been available to CAI courseware authors until recently, except in a limited degree on the PLATO system. It requires a substantial amount of processor time, especially if movement is generated as the program operates rather than being pre-stored. Again, the use of microprocessors has made this facility feasible, albeit in limited form so far. However, it will be necessary for courseware authors to learn how to use it effectively. For example, an animation in color of the operation of an internal combustion engine could be extremely useful, as could animation of experiments in a science laboratory.

A prerequisite for the adequate and widespread use of graphics, color and animation, is appropriate software. Many CAI languages do not yet provide the courseware author with easy-to-use facilities to draw straight lines, polygons, and circles; to specify colors; or to develop animation. Not only is it necessary to have available the basic commands; it is also important to have a library of functions or subroutines which with the addition of a few parameters will produce a variety of figures. The NRC language NATAL-74 is at the present time the only non-proprietary language which will likely provide such facilities on a variety of computers in the foreseeable future.

It should be noted that, for the input of pre-stored graphics, relatively inexpensive "graphics tablets" are now available which can be attached to a number of microcomputers. Also, the NRC has been instrumental in developing a "graphics composer" system which will likely be commercially available in the near future. This will allow a courseware author to pre-store graphics by photographing his material and recording it directly in digital form within a computer.

Specialized Input Devices

Many specialized computer input devices are now available which may be used in addition to, or sometimes instead of, a standard keyboard. All are intended to make it easier to interact with a computer, and many are relevant to CAI. Frequently, they have been developed specifically for CAI.

Some provide a simplified means of input which takes advantage of a natural action such as pointing. Lightpens and touch sensitive devices fall into this category. The former have been operational for many years, but have been too expensive for general application. They can now be purchased for less than $50, together with the necessary application software, and can be made at a cost of a few dollars. However, they are not suitable for all students. Most lightpens require a rather slow and deliberate pointing, sometimes using a fair amount of pressure; on occasions a second attempt is required to get effective input; and errors may occur due to ambient light.

Touch sensitive overlays may be used with either a terminal display or a rearview screen, or both. The action of pointing a finger or a stylus at the screen comes very easily to a small child or to a retarded learner. An excellent touch sensitive display was developed by NRC (Hlady, 1969) and has been used successfully in several Canadian projects. As already described, this employes ultra-sonic waves which cross the screen both vertically and horizontally, and has the advantage that the waves bend with the curvature of a CRT screen. This display has been used in medical projects, and is presently available from Megadata, of Kanata, Ontario.

Another touch sensitive device uses light emitting diodes and photosensitive transistors to produce a grid of vertical and horizontal lines. As implemented in the PLATO project and by Lektromedia of Montreal, there are 16 lines both horizontally and vertically to cover a plasma display or CRT screen respectively. Early models had problems with ambient light, and with movement of the diodes, but these appear now to have been overcome.

Another touch sensitive display consists of two transparent plastic sheets attached to the surface of a CRT display and .03 inches apart. On the surfaces of these sheets which face together are very fine stainless steel wires running horizontally on one sheet and vertically on the other. A light touch with the finger causes the two sets of lines to meet near the point of touch. The system was first developed by Westinghouse Research Laboratories for the Learning Research and Development Center at Pittsburgh. It is now a standard feature of the CDC PLATO terminal. Its reliability over a period of time is still to be proven. However, if such problems can be overcome, it could prove to be a very acceptable device.

The joystick controls now available for many microcomputers, and for computer games, allow a user to move the CRT cursor to a desired position on the screen, and to either input or move a selected character.

Numerous input devices have been developed to allow physically handicapped persons to communicate with a computer. In the University of Calgary project, for example, several devices are intended to enable cerebral palsied persons to use CAI programs. A large and robust keyboard has recessed keys so that users may lean on it and slide their hands above the keys before selecting the one to be depressed. If a key is depressed by accident a delay gives time for a second choice. POSSUM apparatus allows the user to move a light horizontally and vertically in a display unit in order to select a desired character which may then be input. Devices to control the movement of the light include a joystick, dual rod control, headswitch, footswitch, hand control, and pneumatic control. In effect, it is possible to use CAI programs or even to program the computer by sucking and puffing on a mouthpiece. Similar apparatus has been developed by the National Research Council Medical Electronics Section, and is available in Canada.

Other specialized devices are intended to allow the user to input answers to a CAI program in terms of immediately relevant concepts. They could perhaps be referred to as "concept keyboards", because they allow the user to think in terms of a concept without the necessity of translating it either to natural language or to some related number. In the Calgary project, for example, when developmentally handicapped users learn money handling and shopping by CAI, they can use a keyboard on which the keys are actual bills and coins. To make a response, they touch the bills and coins: the CAI is as close as possible to the real life situation. For a program on nutrition there is a special keyboard on which the keys represent food groups as illustrated by photographs; a "time sense" keyboard has only three keys for early, on time and late; and a section of bubble pad keyboard is used to convert a cash register into a computer terminal, so that cashiers may be trained by CAI. However, concept keyboards are not only used in programs for the developmentally handicapped. They have also been employed in teaching statistics to graduate students, and could be applied in many other contexts.

Videotape and Videodisc

Videotape Players

An appraisal of multi-media terminals used for CAI leads to the conclusion that there is an urgent need for improved audio. It is also apparent that a new technology is required for image projection, to provide a larger number of still images without the need to change an 80 slide carousel, and to provide moving images.

Videotape players have benefitted from a number of technological advances, and can now be used under computer control. A videotape player computer interface, known as the Digital and Interactive Video Device (DAVID), was produced by Video Associates Laboratories of Texas in 1977. Together with a Sony player, this costs $5,000 U.S. It can be interfaced with a variety of microcomputers, and has been very effective in use (von Feldt, 1978; Cronin, 1979). An improved version is under development.

Both Panasonic and Sony produce videotape recorder-players with automatic controllers which allow forward, fast forward, freeze frame, single frame advance, rewind, and selection of a specific frame. Such controllers may be interfaced with a microcomputer, and a 10% error rate in single frame selection can be accommodated by recording several copies of any frame to be used as a still. However, there is so far little experience in the use of videotape as part of a CAI terminal and several problems remain, not the least of which is the high cost of maintenance.

An obvious disadvantage is the slow rate of access in a medium which is essentially sequential. In fact, the problems experienced with the audio tape may well be experienced again with videotape. On the other hand, a videotape player might be the appropriate device to use in the development of a CAI program which requires moving images, or more stills than can be held in one 80 slide carousel; and when compared to a videodisc player, it is comparatively inexpensive where few copies of a program are required.

Videodisc Players

Videodisc players have been under development for a considerable number of years and are now becoming commercially available. They are basically of three types: one uses a stylus running in grooves on the disc, a second uses a stylus which moves close to the surface of the disc, and a third employs a low powered laser instead of a stylus.

Videodisc players of the first type have been developed by RCA and AEG-Telefunken. The RCA Selectavision player is due to be marketed throughout North America, at a cost of approximately $500 U.S., with a large catalog of entertainment discs. However, it is not considered that players of this type will be appropriate for CAI owing to the wear on both disc and stylus when a still frame is shown for a protracted period.

Early in 1980 Matsushita Electric announced a decision to adopt a videodisc player of the second type. This uses capacitance variations between the disc and a sapphire or diamond stylus to detect information. Since there is no physical contact between the stylus and the disc wear is reduced, so that it is claimed the stylus will play for 2000 hours and the disc 10,000 times. It is therefore possible to display still frames and to use other features such as random access, variable speed forward and reverse, and two-track audio, which are typical of the optical laser players. Since the players can use standard components and the discs can be manufactured using much the same equipment as a traditional audio disc, costs are substantially reduced and there are fewer production problems. The system is referred to as VHD, since it has "very high density" and can use 10.24 inch diameter discs which, compared to other videodiscs, are comparatively small. This alone could cut production costs by 25%. Commercial production is likely to start in 1981, with VHD players costing around $500 and discs $15. There is a strong possibility that the system could become the standard in Japan. However, it is not known whether it would be appropriate for CAI. Further, Matsushita retains an interest in optical systems as the parent company of Japanese Victor; and it is possible that VHD discs, given a reflective coating, could be used on optical players.

The third type of videodisc player, which uses a low powered laser as the reading device, has the greatest relevance to CAI at the present time. Optical disc systems of this general type have been developed by Magnavox, a Philips company in the U.S.; Universal Pioneer, a joint venture of MCA in the U.S. and Pioneer in Japan, using the Philips technology; Thompson CSF, in France; and Hitachi and Sony in Japan. All use 12 inch discs which may be read a very large number of times without any deterioration in quality of reproduction.

Videodiscs

The Thompson disc is floppy and transparent, and contains information on both sides. Further, both sides may be read without removal of the disc from the player, by changing the angle of the laser. However, the disc must be kept in a protective cardboard jacket and must be handled with care. Otherwise, the Thompson system is comparable in function and price to the Universal Pioneer system: the player incorporates a microcomputer which allows program control of the display; it has an IEEE port which allows connection to an external computer; and, although in Europe it is built to PAL/SECAM television standards, it is also available using North American standards. In Canada, the system has been tested by the Department of National Defence and by Federal Archives. However, there is at the present time no center in North America for the mastering of discs, and no service organization.

The disc used in systems based upon the Philips technology is rigid and opaque, and may be used on one side only without being physically turned. Since it is coated with plastic, it may be handled with comparatively little danger of damage from fingerprints, dust and dirt. It complies with the National Television Standards of North America. Further, players are now becoming available from two sources in the U.S., a few service centers are already in place in the U.S. and in Canada, and there is a disc mastering facility in California. It is considered that this type of player is most likely to be used for CAI in Canada, therefore it is discussed in greater detail.

However, it should be noted that the Philips type videodisc player, which was first publicly demonstrated in Chicago in 1972, is now available in two versions: an industrial/educational player manufactured by Universal Pioneer, and a home player manufactured by Magnavox.

The discs used by the two players are almost identical: they are 12 inches in diameter, one-tenth of an inch thick, and weigh approximately 6.5 ozs. One side of the disc will contain 54,000 separate frames of information, each occupying one circular track on the disc and having a unique number. One frame for display on a color TV monitor is generated by each rotation of the disc and, since the disc rotates at 1800 revolutions per minute and 30 frames per second are used to produce motion sequences, the disk may be used to hold 30 minutes of continuous motion. Alternatively, the 54,000 frames may be used as stills, or as a mixture of motion and stills. Variable forward and reverse speeds may be used, from slow to rapid scan, also single step forward and reverse. Most important for use in CAI applications, there is direct access to any given frame in approximately 4.5 seconds or less. Two tracks of high fidelity audio are available when standard speed forward motion is used.

Information is represented by oblong micropits in the surface of the disc. As the disc is read by the laser, the pits moderate the light beam and so generate a signal which is translated into electronic impulses. The images appearing on the TV screen are equal to those obtained from high quality cable television.

Instead of analog data, digital data may be stored on the disc. When used for digital storage only, one side of a disc could hold more than 1.25 billion characters. This is far in excess of any computer disk yet available. It has been estimated that, stored in this manner, the entire Encyclopedia Britannica would occupy no more than four per cent of one side of one disc. Using a compressed form of digitized audio, one side of a disc would store 150 hours of music (Braun, 1978). The digitized information could represent computer programs or data. Alternatively, the disc could hold a mixture of programs, speech and pictorial information. However, it should be remembered that a videodisc is a read only device at the present time.

Industrial/Educational and Home Players

Of the two Philips-type videodisc players which are now available, the Universal Pioneer industrial/educational model is likely to be the first on which CAI is implemented. In the present version, it contains its own Fairchild microcomputer, and has a remote hand control which will transmit infrared signals to the player. The hand control may be used to read a program with 1024 steps into the microcomputer. Frames on the disc may be designated by number, and a program may cause the player to search for a specific frame, play to the next specified frame, stop, repeat with the other audio channel, freeze frame, etc. For short programs, and to produce an endless loop in a video program playing in a sales showroom, the system is adequate.

For more extensive programs of the kind needed for CAI, it is simpler to have the program on another computer which is interfaced with the videodisc player. This presents no significant problem since the player is provided with a standard communications channel to the Fairchild microcomputer. At Brigham Young University, a player is controlled by a Billings Data-Byte Microcomputer System I, which uses an 8080 chip. The University of Utah in Salt Lake City has interfaced a Terak microcomputer which is based upon the DEC LSI-11, and has developed an authoring system based upon PASCAL. Other microcomputers which have also been interfaced with the Universal Pioneer videodisc player include the IMSAI, the Radio Shack TRS-80, and the APPLE II. Woolley (1979), for example, gives a list of the syntax and commands used for an APPLE II configuration.

The Magnavox videodisc player for home use, known as the MagnaVision player, does not incorporate a microcomputer and has push button controls only. These allow variable speeds for both forward and reverse motion, also step by step movement and freeze frame. The search for a specific frame must be made under manual control whilst frame numbers are displayed on the screen.

Since this player costs approximately $1000 CAN, as against approximately $4200 CAN or more for the industrial/educational player, there are attempts in several projects to interface the MagnaVision player with a microcomputer. Some of these already claim success, despite the problems: frame numbers in digital form can be picked up from the disc and transmitted to the computer, but there are difficulties relating to the slew of the reading head. However, it is expected that within one year or 18 months Magnavox will produce a player which incorporates its own microprocessor.

At the present time, the home player is readily available in the Atlanta and Seattle areas, and will likely be marketed widely by late 1980. The industrial/educational player has not been easy to obtain. The total production of Universal Pioneer to approximately the end of 1979 was reserved for General Motors, who had ordered more than 10,000 machines for training purposes and showroom demonstrations. It is possible that bulk sales will be made to other automobile manufacturers and to travel firms such as American Express. However, it is expected that the industrial/educational player will be available in Canada in 1980.

In mid-1979 IBM bought a half interest in the Universal Pioneer enterprise (sometimes referred to as MCA/Philips) and a new company, DiscoVision Associates, was set up. This may well lead to the further development of computer applications of videodisc technology; and it has led to the production of another home videodisc player by Universal Pioneer in early 1980. Also, in late 1979, Sony demonstrated in the U.S. a videodisc player which very closely resembled the Philips/Magnavox player. This system could well become an industry standard during the rapid expansion which is generally expected. It has been predicted that, by the end of the decade, whilst nine million U.S. homes will have computers, 31 million will have videocassette or videodisc players.

Videodiscs and CAI

The great advantages which videodiscs offer over other audio-visual media ensure that they will be used for CAI, almost certainly on a very large scale.

When a videodisc player is interfaced with a microcomputer, the two become a very powerful multi-media CAI station, with a large number of stills or moving images in color, and two audio channels. Two monitors may be used, one for display from the videodisc player and one for display from the microcomputer. A system of this type is under development at the World Institute for Computer Assisted Teaching (WICAT) in Utah, with support from the National Science Foundation, and has been referred to earlier. Both monitors may use color; and both could use graphics and animation provided that the microcomputer driving the second display is sufficiently powerful, as it is likely to be in the future. Alternatively, both devices could send their display to the same monitor. This latter procedure is being tried at the University of Utah in Salt Lake City and could, of course, reduce the cost of a CAI station. However, a considerable amount of empirical work will be required in order to determine the optimum configuration of such a multi-media station. Whilst it is possible to argue that images and printed messages should appear on one screen only, there are the problems of reducing or obscuring part of the image, and of having insufficient space to display the message. For example, it might be desired to retain an image while displaying a succession of multiple choice test items, or while allowing the student to use the computer to perform a series of calculations.

It is possible that the work at WICAT and the University of Utah could result in the development of an improved and much less expensive TICCIT-like system, incorporating some of the advantages of PLATO. All the present TICCIT language and mathematics courseware could be put onto one and a half sides of a videodisc.

Costs may also be reduced by recording part of the CAI program on the videodisc. Data read from the disc by the computer could be used to drive a small computer program, using "data base driven" CAI. This would require only a small microcomputer with a relatively small memory. However, with the current reduction in computer hardware costs, it becomes questionable whether this approach would save enough to justify the reduced flexibility of the program. For several years at least, it is likely that programs will be frequently updated in order to make optimum use of the videodiscs.

An interesting reflection, however, is that the large amount of storage on a videodisc will produce a trend towards CAI which uses stored information, and away from "generative" CAI.

A proposal has been made to produce discs which could be used on the hand controlled home player, and to interpolate an occasional frame of digital information. One frame can hold over 23,000 characters, sufficient to provide data for a long program, and would not noticeably affect the continuity of a motion sequence. The same videodisc could therefore be used for CAI on the industrial/educational player.

Several projects are already committed to the development of videodiscs for use in CAI, and a few educational discs have already been produced (Merrill and Bennion, 1979). Subject areas range from metrics and parent education for adults, to Spanish pronunciation at high school level and gymnastics at elementary level. Special education is not neglected: several discs are intended for the retarded and the hearing impaired. It is probable that videodiscs will have particular relevance to many forms of special education. The mix of images and audio is needed for the developmentally handicapped, the visual images are needed for the hearing impaired, and the digitized audio, which can provide more than 400 hours of speech on one side of a disc, could prove useful for education of the partially sighted.

A problem in using videodiscs at the present time, however, lies in the production of the discs themselves. The master discs are produced by MCA, using equipment costing between one and two million dollars U.S. Copies are then made in plate glass, using an injection molding process. The cost of the master is $4500 for two sides, and the base price of a disc is $18. When large numbers of discs are purchased the cost of the master is reduced, so that at 3000 discs it is free.

For the production of the master, a pre-master is used which contains an exact copy of all the materials to be recorded on the videodisc. This must be in two-inch quad format videotape. Since the original materials are rarely in such a format, and since few educational institutions have the necessary equipment, the main problem facing the developer of CAI courseware is to produce the pre-master.

The original materials may be on varying types of slides, films, videotapes, and microfiche, or a mixture of these. The problem is to assemble these materials, in correct sequence, onto the two-inch quad format tape, and to check that the assembled pre-master is accurate. An intermediate stage may be the assembly of the materials onto other videotape or onto film, which may then be converted commercially into two-inch quad format tape. If film is used, editing is easier but production costs are likely to be high if real life situations are to be recorded. If videotape is used, there are problems in ensuring that stills are recorded in the correct place on the tape, and in checking that they are correctly recorded. Equipment is available to overcome such problems, by controlling the videotape to produce a single copy of each of a sequence of stills. The cost of such equipment is variously estimated from $5,000 for a simple authoring system for three-quarter inch videotape, up to $25,000 for a system using a magnetic videodisc, or $150,000 for commerical quality videotape production. At the present time there is insufficient experience to determine which equipment should be used; and various procedures are under consideration, or have already been used, by different projects.

It is possible that the development of low cost digital video recorders will solve many of the present problems. Also, some authoring difficulties may disappear, following the evolution of videodisc technology during the 1980's (Kribs, 1979). However, if CAI based upon videodiscs is to be extensively used in Alberta, it will be necessary to have local facilities for the production of pre-masters.

At the end of 1978, a direct read after write (DRAW) facility was announced by Philips Data Systems. This allows direct recording to the disc by the user, with very fast random access for retrieval. When commercially available, the system may effect another advance in CAI.

Meanwhile, second generation discs may incorporate sound tracks which contain compressed audio, and some may contain other digitized information. The former, being no more than a 15 second message, could be read into the memory of a microcomputer and could then be played whilst a video frame was shown on the monitor. However, there are problems of transmission speed and storage to be solved.

The advantages of videodiscs for multi-media CAI are well understood in the centers where projects to develop such systems have appeared since mid-1978. It should be emphasized that almost all the information and expertise have appeared since that date, and mostly during 1979. This is a very new technology. However, it promises to supplant much of the CAI which has been developed so far, and to produce more efficient and effective student learning. The equivalent mix of digital information, images, moving sequences, and audio in an interactive system, in any combination, has never before been available. It will likely take time for courseware authors to use it to optimum advantage, but there is no doubt regarding its potential to promote individualized learning, open education, in-service professional education, and education for semi-literate and semi-numerate adults.

Communications

From the standpoint of those interested in CAI, and following a careful appraisal of developments in microcomputers and videodiscs, the recent developments in communications are at the present time something of a disappointment.

This is in no way to disparage the remarkable developments which have taken place, nor is it to suggest that developments in communications will not have very important implications for CAI in the future. It is simply to assert that whereas, a few years ago, it was rather difficult to determine whether CAI would become centralized on large machines owing to the reduced cost of communications, or distributed to small machines because of the reduced cost of computers, the answer is now quite clear. The cost of computers is coming down much faster than the cost of communications, and the immediate future of CAI lies with microcomputers.

There is still, however, the question of the more distant future. When the presently available technology is in place, and costs allow, communications systems in the form of videotex are likely to play a very significant role in CAI.

Videotex, sometimes referred to as viewdata, is essentially interactive television, in which a user is able to send a message over telecommunications lines to a computer which then responds. As distinct from this, teletex systems broadcast at regular intervals pages of information, which can be selected for display on a television set by a user pressing the appropriate button on a control box.

Videotex is already in commmercial operation in the U.K., and is under active development in France, West Germany, Japan, the Netherlands, Finland, Sweden, the U.S. and Canada.

The British Post Office started market trials of a videotex system, Prestel, in 1978. By 1979 it had 150,000 pages of information, provided by 160 different contributors who either store their own data bases or rent storage space on the Post Office computers. The telephone system is used for communication, and users rent a terminal which is an augmented television set, with either a small keypad or a full size keyboard. Unless the owner of the data base provides it without charge, users pay approximately three pence per page; and it is estimated that the cost of a typical call will average ten pence.

Prestel is essentially a first generation system, in that it allows transmission in color of characters, and simple graphics with a definition of 60 x 80. However, it is already in use for some educational applications. The Council for Educational Technology (CET) is supplying general information about education and will soon have a data base of 5000 pages, some sub-let to other educational agencies and some not yet filled. The hope is that information providers will supply revenue to make the service self-financing and free to users. Thirty-two terminals are installed on a trial basis for one year, in part as teaching aids and for curriculum enrichment. Considerable evaluation will be required before it is determined if and how such a system can profitably be used for CAI.

However, Prestel could also store computer programs, and could possibly become the most efficient system for distribution of software and courseware. CAI programs could be stored in the data base and downloaded for local operation on a microcomputer. CET is therefore developing the required software for a microcomputer, the manufacturer is developing the necessary hardware, and the hope is to set up a national distribution system. The perceived problems relate primarily to the ease of operation, standardization, reliability, and documentation of courseware.

Another CET project is intended to make use of teletex to broadcast computer programs to television receivers which have been converted so that they are also microcomputers. When an educational television program is broadcast, and whilst it is being viewed or recorded, a CAI program will be simultaneously transmitted and recorded in the receiver. Following viewing of the television program, the matching CAI program will provide appropriate simulation or problem solving exercises. Again, a one year trial period will be used to provide guidelines for further work on such projects.

The Canadian videotex system, Telidon, is a second generation system in that it uses a geometric approach in which characters and graphics are defined by means of seven Picture Description Instructions. The PDIs are: Line; Area, for rectangles; Arc; Polygon; Point; Bit, for photographic mode; and Control, to indicate attributes such as color for the other instructions. The system provides considerable flexibility. Resolution may be the same as in Prestel, namely 60 x 80; or 192 x 256, which is the current resolution; or 960 x 1280, which may be used as the technology becomes cheaper. At the present time, communication is via telephone line, with speeds of 1200 baud (bits-per-second) from computer to user, and 75 baud for return. The user may have a simple keypad to perform information retrieval by searching a tree structure; or, later, a full keyboard may be available.

The National Research Council has already begun to enter CAI programs into the Telidon system, using Natal-74 as the language. A CAI terminal has been modified for this purpose.

The promise held out by videotex is very impressive. However, widespread use for CAI is quite obviously several years into the future and at the present time it is not possible to foresee what shape it will take. Prestel will be little used for CAI for some time to come, except possibly for the distribution of software and courseware; and Telidon, as a second generation system, is at present more expensive and will take longer to bring into widespread operation.

Meanwhile, note should be taken of the microcomputer networks, such as Micronet, which are rapidly coming into use in the U.S. For the distribution of sofware and courseware, these may well provide keen competition with videotex.

CHAPTER 4

FACTORS IN THE FUTURE DEVELOPMENT OF CAI

The examination of significant ongoing projects demonstrated some of the achievements which may be attributed to CAI to date, also some of the limitations. The survey of present technological developments suggested that, as far as can be predicted, CAI will take a somewhat different direction in the future, using microcomputers in multi-user processing systems, and multi-media terminals incorporating videodiscs. It also implied that CAI will probably develop at a more rapid rate. An important change is occurring: the technology is becoming pervasive throughout our everyday lives and its potential value in student learning is attracting the attention of more people concerned with education.

Given this situation, therefore, the purpose of this chapter is to consider other factors relevant to the future development of CAI. These are identified as cost, cost/benefit as related to student achievement and attitude, and matters relating to the integration of CAI into the ongoing instructional setting in public education. There is also a consideration of those parts of the curriculum in which CAI appears most likely to be effective at the present time, of the availability of courseware, especially in relation to the ever present problem of CAI languages, and of the need for the training of teachers and future teachers in computer applications.

Cost

In almost all the ongoing projects reviewed in chapter two there was some preoccupation with costs. Where this did not exist, as in some locations in West Germany, the projects have gone out of existence.

This concern with costs was, and is, very proper. When it is introduced into an ongoing instructional setting, CAI is almost invariably an add-on cost. There is virtually no instance in public education where CAI has been introduced as a replacement cost, in that other existing expenditures have been saved; and there are few cases where it can be claimed that the introduction of CAI has saved an institution from increasing other costs at a later date. When an attempt was made in the TICCIT project to save instructor time, student performance was lower and the drop-out rate was higher; and the conclusion was that such saving of instructor time should not have been attempted (Bunderson, 1978).

This in no way implies that, with the use of CAI, there is not an overall cost/benefit. Students using CAI may receive a better quality of education, and teachers may be able to use their time more effectively. However, an add-on cost must necessarily be examined carefully.

The principal costs of CAI arise from the costs of computer hardware and software on the one hand, and the costs of courseware on the other. For both, there are maintenance and operating expenses. Frequently, there are also operating expenses arising from communications costs.

Cost of Packaged CAI Systems

It is instructive to examine the cost of turnkey CAI systems which may be obtained commercially. Three such systems are available: the CCC drill and practice system, the Hazeltine Corporation TICCIT system, and the CDC PLATO system.

Each of these has already been discussed in some detail. It was concluded that the CCC system, although comparatively inexpensive and widely used in the U.S., was inappropriate for use in Alberta for several reasons: it is not possible for a user to change the existing courseware or develop new courseware; also the present courseware offers drill and practice only and does not match the Alberta curriculum. The TICCIT system was also considered inappropriate because parts of the technology used are already becoming outmoded: managers of the system at Brigham Young University are already looking to the possibility of a new system based upon videodiscs. Further, a TICCIT system does not allow use of remote terminals connected by phone lines and is not designed for use in a small community; also, experience has shown that some courseware authors find the authoring system too restrictive.

The PLATO system, however, is being actively marketed by CDC and new technology is being introduced by the company, particularly into the terminals.

For a 32 terminal system, the capital cost of PLATO central site hardware in 1978 was quoted at $1,458,482, with an associated cost of $7,255 per month for maintenance. This gives a cost of $45,577 per port, plus maintenance. A terminal was quoted at $5,856, with a maintenance cost of $46 per month, giving a total for 32 terminals of $187,392 capital cost and $1,472 per month maintenance. The complete 32 terminal system, therefore, was quoted at $1,645,874, plus $8,725 per month maintenance.

For a 224 terminal system, the capital cost of central site hardware was $2,575,634, with $11,995 per month for maintenance. This gives a cost of $11,498 per port, plus maintenance. With a larger number of terminals the cost per port is substantially less.

The initial capital cost is obviously high when perceived from the standpoint of a school or a school board.

Five year lease prices for central site hardware were $32,355 per month for a 32 port system, and $60,752 per month for a 224 port system. Maintenance costs were additional, and the same as for purchased systems.

The cost of software and courseware was additional. The network operating system cost $61,835, plus a monthly service charge of $974; the FORTRAN extender cost $11,782, plus a monthly service charge of $213; and the PLATO software cost 20 cents per hour per terminal, with a minimum monthly charge of $168 and an initial software installation fee of $5,600. The cost of the supplemental PLATO courseware library was 30 cents per hour per terminal, with a minimum monthly charge of $112. For the Basic Skills Library, the cost was 60 cents per hour per terminal, with a minimum monthly charge of $112.

As indicated by Kearsley (1977) the low projected cost of a PLATO system has not been met in practice. The cost of the commercial version of the system is too high for use in the public schools. Even in the case of the University of Illinois PLATO system, schools find the costs too high and discontinue use of terminals when no longer supported by outside funding.

Since the present commercially available turnkey CAI systems appear inappropriate for use in the public schools, it is necessary to examine the cost of other hardware and software which can support CAI.

Computer Costs

Throughout the brief history of CAI, the principal concern of most projects has been to obtain the capital or operating budget to purchase or lease a dedicated time-sharing computer. This has been the largest single expenditure, and a necessary first hurdle to be overcome. However, it is a expenditure that is becoming progressively smaller as time goes on.

A useful indicator of the cost of a time-sharing computer is the capital cost per port. In 1977, for example, the cost of the PDP 11/70 computer with 48 ports and an 88 megabyte disk was between $200,000 and $250,000, depending upon the precise configuration. This gives a cost per port of approximately $4000 to $5000. Amortized over a period of five years, this is $800 to $1000 per annum; over six years, it is $666 to $833 per annum.

In estimating the cost of CAI, a per student hour figure has frequently been used. If it is assumed that a school year consists of 200 days, each of five hours, the above figures give a cost of between 66¢ and $1.00 per student hour. This compares with an overall cost of education per student hour for the Calgary Board of Education in 1979 of $2.22.

It is, of course, improbable that all ports on a computer would be in use continuously from 9:00 a.m. to 12:00 noon and from 1:00 p.m. to 3:00 p.m. on each of 200 school days per year. However, experience has shown that some ports are used as early as 7:00 a.m. and as late as 5:00 p.m., and they are available for use at weekends. Also, in the above example, the amount of 1.8 million characters of memory per port is excessive for CAI in schools. As indicated earlier, it is sometimes considered that 150,000 characters per port are sufficient. All factors considered, 66¢ to $1.00 probably represents a reasonable estimate of central computer costs per student hour using a PDP 11/70 in 1977.

Estimates in 1979 from Digital Equipment Corporation for a PDP 11/44 with 32 to 48 ports give a cost per port of $1500 or less. Comparable estimates for the Honeywell Level 6 start at approximately the same level, but reduce to less than $1000 if a large number of ports are used. Over a period of five years, this gives a cost per student hour of 20¢ to 30¢. This is a substantial cost reduction between 1977 and 1979. On the basis of computer hardware, it is becoming possible to justify CAI as a tool for the teacher. Moreover, present estimates are that such hardware costs are reducing by at least 25% per annum.

It is also necessary, however, to consider the initial capital outlay that is required. It is argued elsewhere in this report that CAI will likely be most acceptable to teachers and most effective if it is provided by a computer located in the school and under the control of the school staff. In the rural areas of Alberta this approach is further necessitated by the high cost of communications lines. However, it is virtually impossible to find a school, ready with instructional organization and courseware, that could quickly make use of 32 or more ports. A capital outlay of $40,000 or $50,000 for a mini-computer therefore appears excessive, particularly when it is considered that the cost of the 32 terminals will require approximately the same amount of additional capital.

If microcomputers are used, the initial capital outlay is significantly less. The question therefore is, can comparable costs per port be achieved using microcomputers? It has already been argued that, for adequate CAI in a school setting, a centralized record keeping system is required. The question therefore becomes, are there available time-sharing or resource-sharing microcomputer systems at a cost of $1000 per port or less? At the present time, the answer is that such systems give a cost of around $2,000 to $3,000 per port and are, for the most part, limited to a maximum of approximately seven ports.

However, this situation is likely to change during the 1980's. As indicated earlier, 16-bit microprocessor systems will become available, with multi-user software using hard top disks. These should support up to at least 16 users on a school CAI system. It may reasonably be expected that for this number of users, and possibly for a smaller number, the cost in the near future will be $1000 per port or less. This will give an initial capital outlay which is not too high for a school or school board to contemplate, and a cost per student hour of 20¢ or less.

Terminal Costs

The cost of terminals is additional and, typically, is approximately equal to the cost of the computer. At the present time the cost of a hard copy or CRT terminal is around $1500. Amortized over five years, this is approximately 30¢ per student hour. Again, however, as chips are brought into use to drive CRT terminals, costs will be reduced.

On the other hand, the price of a multi-media terminal may be as high as $5000 at the present time, with at least $1000 of the total being the cost of image projection devices. Although such terminals will likely become less expensive during 1980, major reductions will wait upon the further development and reduced costs of videodiscs. This is expected to occur in the longer term, but hardly within one year. However, the first need for multi-media terminals is in those situations in which the cost per student hour of education is already high. For example, in the case of students who have developmental handicaps, impaired hearing, or learning disabilities, effective education demands a high teacher/student ratio. For the Calgary Board of Education the cost of special education per student hour in 1979 was $5.56. A CAI terminal at even $1.00 per student hour is therefore not necessarily expensive if it helps the teacher to provide a better quality of education.

A home microcomputer may be used as a terminal and, assuming a cost of approximately $1500, is comparatively inexpensive for this purpose. It may, moreover, provide additional facilities such as color or graphics which place it between a CRT terminal and a full multi-media terminal, but may have disadvantages relating, for example, to the number of characters on the screen. With the addition of a floppy disk, it may also become a stand-alone system to provide CAI without any centralized record keeping facilities. This avoids the cost of the central computer, but will provide less effective CAI and give significantly less assistance to the teacher, whilst saving less than 10¢ per student hour. Further, such saving will become progressively smaller as total costs are reduced.

It is considered that, in the longer term, stand-alone microcomputers for CAI are not justified. However, it cannot be denied they are useful in promoting computer literacy, and in introducing certain forms of CAI into the educational system.

Hardware Maintenance and Communications Costs

Maintenance costs of hardware should be taken into account before purchase. For hard copy terminals, maintenance contracts of $30 per month have not been uncommon in the past. Maintenance costs of multi-media terminals can also be comparatively high at the present time. However, electronic equipment is more reliable than mechanical equipment, and maintenance costs of both computers and display type terminals are becoming proportionately less. On the other hand, facilities for maintenance are essential. They may entail specific arrangements with suppliers or, in the case of large school boards, the need for skilled staff.

Communications costs have frequently been a significant expense for CAI projects in the past. Inevitably, they will also be incurred in the future. However, if CAI is developed primarily using a microcomputer system within a school, communications costs will be at a minimum for several years. Ultimately, there will be an expressed need for communications between microcomputers, but this is not perceived as a need arising directly from the use of CAI. Further into the future, however, there likely will be communications costs relating to CAI distributed via Telidon; it is not yet possible to foresee the nature of such requirements.

Software and Courseware Costs

The "unbundling" of hardware and software was expected to lead to a significant increase in the costs of computer systems software and languages. In those areas of computing considered relevant to CAI in the schools, this can hardly be said to have occurred. The costs of both mini-computers and microcomputers, quoted above, included the software and languages needed to develop CAI. Since emphasis has been placed on microcomputers, it should be indicated that current multi-user software systems for such microcomputers cost approximately $350, and specific languages between $100 and $500.

Courseware, however, is a very different matter. It is considered that, for the most part, this will have to be developed locally. Based upon the findings of the PLATO Project, an experienced CAI developer requires approximately 30 hours to produce one hour of courseware. Assuming a teacher's salary to be, on the average, $20,000 to $25,000 for a 1000 hour contract year, the cost of one hour of CAI courseware developed by a teacher would be between $600 and $750. The cost of 100 hours of CAI courseware would be between $60,000 and $75,000. In other terms, one teacher given release time for one year could produce approximately 33 hours of CAI courseware.

Moreover, it should be considered that few teachers can be regarded as experienced CAI authors, and few CAI systems are as supportive of the author as the PLATO system. The cost of courseware development is therefore likely to be substantially higher in practice than the calculations suggest.

Courseware requires constant maintenance and, like hardware, is likely to become obsolescent within several years. Further costs are therefore incurred, beyond those of the initial development.

It is important to recognize that, whilst hardware costs are likely to be less than educators originally anticipate, courseware costs will almost certainly be higher. It has sometimes been assumed that CAI can be introduced by providing hardware only; or that teachers can produce all the necessary CAI programs with a minimum of release time. Such assumptions merely ensure that CAI will not succeed. Very few teachers are competent programmers; still fewer have training and experience in writing CAI programs. In effect, most teachers are less likely to write all their own CAI programs than they are to write all their own textbooks. They are even less likely to design and implement the management systems required for large scale CAI systems.

On the other hand, with any necessary training and assistance from resource persons, teachers given adequate release time could, and should, participate in the design and the development of effective courseware having local relevance. Moreover, having participated in such development, they would be in a position to implement and evaluate the effectiveness of such courseware. The implication should be noted that, in order to develop effective courseware, resources are necessary to form a courseware authoring team.

The alloction of teacher time for the development of innovative forms of instruction is, of course, no novelty. In the present case the danger is simply that, because of the prestigious connotations of the word "computer", the greater cost of human and professional involvement could be overlooked.

The discussion has also indicated the need for the involvement of resource persons able to facilitate the development of CAI courseware by teachers, and possibly to develop some courseware.

Obviously, the costs involved indicate the need for a strategy of progressive development, which will be guided by considerations relating both to the obtaining of maximum cost/benefit now and in the future, and to the establishment of a base upon which to build further.

Student Achievement and Attitude

The cost/benefit situation promises to be more than merely satisfactory, however. The surveys of current projects of major importance have already indicated that CAI can be effective in producing higher levels of achievement and very positive attitudes towards learning. This has been a common finding whenever CAI has been used over a period of time.

Student Achievement

CAI has generally been introduced into schools as a supplement to ongoing instruction. Summaries of studies in the 1960's and early 1970's showed students receiving CAI in this manner generally had a higher level of performance than students who did not receive CAI (Jamison et al, 1974; Edwards et al, 1975). A recent survey (Thomas, 1979) has indicated positive effects on achievement in mathematics (Bukoski and Korotkin, 1975; Taylor et al, 1972; Wright, 1977); biology (Broderick, 1974); problem solving in physics (Hughes, 1974); algebra (Morgan and Richardson, 1974); and reading (Fricke, 1976). In the Los Nietos Elementary School district the use of CCC materials led to a reversal of a decline in achievement test scores which had continued over 16 years.

Such reviews indicate that, in the great majority of cases, CAI has produced better achievement. Moreover, this is the case whatever the form of CAI: drill and practice, tutorial, or problem solving; whatever the type of computer system: CCC, PLATO, or IBM; whatever the test instruments used to make the measurements: teacher-made test, local test, or standardized test; and whatever the grade level: elementary, junior high, or high school. In some cases the improvement in achievement was dramatic. Further, there are generalization effects; Wontner (1978), for example, showed that use of syllabication programs improved vocabulary performance of elementary school students.

Other studies have shown CAI to be equal to or better than "traditional" instruction. At the secondary school level such results have been reported in connection with mathematics and English (Fletcher et al, 1972), physics (Dunkin, 1977), industrial education (Diedrick and Thomas, 1977), and simulations and games (Roberts, 1976). General reviews have been produced by Bell (1974) and McDougall (1975) of research comparing CAI and traditional instruction, leading to the conclusion that CAI produces enhanced achievement.

When CAI and traditional instruction are compared, however, a common finding is that the equal or better achievement using CAI is obtained in less time. This implied cost/benefit using CAI has been recognized since the early days of the Stanford project. It has also been reported for a variety of elementary school CAI projects (Edwards et al, 1975); for fourth grade to ninth grade mathematics (Johnson, 1974; Cranford, 1976; Jacobson and Thompson, 1975); for typewriting (Wolcott, 1976); for industrial arts (Diedrick and Thomas, 1977); for accounting (Solomon, 1974); and for biology (Arsenty, 1971). However, it should be noted that the possibility of taking advantage of the reduced learning time required by CAI is a function of the way in which a school organizes its instruction. If instruction is completely individualized there is no problem; if instruction is based rigidly on class groups, it may not be possible to take advantage of the potential cost/benefit of CAI.

As might be expected, some studies indicate that the introduction of supplementary CAI made no significant difference in achievement (e.g. Antista, 1974; Fitzgerald, 1974). In at least one such case (Moont, 1978) the lack of such difference, however, could be attributed to the use of too little CAI time for students: the experience with CCC curricula suggests that students should use the computer terminal on a regular basis for ten minutes per day in each subject area.

In some cases, as with the PLATO elementary reading and language project, the CAI students have actually performed less well than a control group, although not significantly so. In this case, the comparative ineffectiveness of the CAI was apparently due to unreliability of the terminal peripherals, which resulted in audio output, image projection and plasma display messages being out of phase.

The evaluation of the PLATO school mathematics project conducted by Educational Testing Service found a significant difference in favor of the CAI group.

CAI for developmentally handicapped persons, who have both mental and associated physical handicaps, is not yet used widely. However, controlled studies at the University of Calgary have demonstrated that it can lead to higher achievement in social arithmetic (Strain, 1974), banking skills (Sandals, 1973), budgeting (England, 1979), and social sight vocabulary (Holz, 1976). An unusual feature of much of this research has been the use of retention tests to determine whether the learning of the CAI programs is transitory, and of transfer tests, to discover whether the learning is transferable to real life situations. In both cases, results have been positive.

A study conducted by the Stanford Institute for Mathematical Studies in the Social Sciences has demonstrated that CAI can produce significant increases in mathematical skills among students with impaired hearing (Suppes et al, 1973). As a result, CAI is now used in numerous schools and programs for the deaf in the U.S. (vonFeldt, 1980).

Student Attitude

Measures of attitude towards CAI are less frequently obtained than measures of achievement and, when they are, may be insufficiently sensitive to the relevant changes. However, positive attitudes have been reported by Roberts (1976) towards simulations; by Johnson (1974), Bukoski and Korotkin (1975), and Huang (1979) towards junior high school and high school mathematics; by Taylor et al (1972), towards elementary and junior high school mathematics and language skills; and by Broderick (1974) towards biology. Crandall (1976) reported less truancy and vandalism in an "ethnic minority" school following introduction of CAI.

The general assessment appears to be that students like CAI. PLATO students, for example, liked the fact that they could make mistakes without embarrassment, wanted to take further PLATO courses, disagreed that PLATO was dehumanizing or boring, felt that they received individual attention, and would recommend the CAI courses to their friends (Alderman et al, 1978).

A common observation is that students using CAI programs exhibit an increased attention span. This is especially noticeable in the case of developmentally handicapped students and has been regarded as one of the important benefits of CAI for such persons (Hallworth et al, 1980).

Integration of CAI into the Instructional Setting

Present developments in technology, and the progressive reduction of costs, have now made CAI a practical proposition in the schools. Evidence regarding the achievement and attitude of students indicates that, if CAI is used under the control of teachers as an integral part of instruction, it can be highly successful and produce a better quality of education.

The problem, then, is to introduce and integrate CAI into the instructional setting in a way that will allow it to operate effectively, on a continuing basis, so that it yields the benefits which have been shown to be possible.

This obviously involves matters relating to teacher attitude and acceptance of CAI, the place of CAI in the organization of learning and instruction, and the availability of courseware for those parts of the curriculum in which CAI is to be used.

Teacher Attitude and Acceptance of CAI

It is unfortunately the case that among the public at large, including teachers, there is a considerable awe of computers which is allied with fear and suspicion. Computers are frequently regarded with something approaching reverence, as being capable of miracles. At the same time they are perceived as threatening, capable of making remote decisions which may divest people of their humanity, and encroaching upon jobs as a preliminary to taking them over.

Many such attitudes and beliefs arise from a simple lack of information. Among teachers, for example, comparatively few had any opportunity during their years of training to learn anything about computers; essentially none had opportunity to learn about microcomputers.

In the case of CAI, it is clear from the discussion in earlier parts of this document that it does not replace a teacher. CAI is simply a tool for the teacher, albeit a potentially powerful and important tool. Certainly, to be adequately used, it demands from the teacher a new expertise; it implies the need for a higher level of professional competence which will have to be recognized. However, it should be emphasized that the Educational Testing Service evaluations of both the PLATO and TICCIT projects, for example, concluded that a vital factor in the success of CAI is the instructor (Alderman et al, 1978). This finding had not been anticipated; it simply became obvious from the accumulated evidence. However, it has now been firmly recognized. Presentations made to the Information Technology in Education Workshop held by the U.S. Congress in March 1980 emphasized that the introduction of CAI into the schools will lead to substantial benefits, provided that the teacher is kept at the center of the instructional enterprise, and in control of it.

An essential factor in the introduction of CAI into the schools is therefore teacher acceptance and involvement.

When instructors have been engaged in CAI projects in conditions which allow them a substantial measure of control, their attitude has been favorable. In the PLATO college project, for example, most instructors (72% to 86%) approved of the CAI lessons. They did not feel that CAI came between them and their students; rather, many felt they had more contact with their students (39%), and few felt that contact was decreased (15%). Most instructors (78%) did not consider their work load was decreased when they used CAI, and one-third of them felt that it was increased. Despite this, most intended to continue using CAI (88%), and considered PLATO led to higher student achievement (80%).

To this must be added the evidence that, at the present time, many teachers are expending considerable time and effort to acquire microcomputers for use by the their students. The number of microcomputers acquired by Alberta schools has increased very rapidly during the last year, and appears to be accelerating. In the spring of 1980, when the University of Calgary Faculty of Education offered an in-service course on computer literacy for teachers, it was quickly oversubscribed.

The introduction of CAI into the schools of the Province, with the support and involvement of teachers, appears both practicable and timely. The question is, therefore, what specific steps should be taken?

All the evidence indicates that, if an attempt is made to develop CAI in Alberta, the most significant problem will be a shortage not of hardware but of competent personnel. A general lack of knowledge regarding computers, among both teachers and students, has been referred to as "The next great crisis in American education: computer literacy" (Molnar, 1978). A comparable crisis in Alberta, combined with a need for more specific expertise among teachers in CAI, suggests that a range of courses on computer applications is required.

In-service courses on computer literacy, CAI and CMI should be made easily available to teachers in the Province. These could most easily be offered by the Universities of Alberta and Calgary and, following existing precedents, could provide graduate level credit. At the same time, consideration could be given to introducing similar courses for teachers presently in training. It would be possible, for example, to introduce a compulsory unit on computer familiarity to ensure that all future teachers have a minimum amount of information regarding computers. Optional units on computer literacy, CAI, and CMI should also be available.

The Faculties of Education at both the Universities of Calgary and Alberta already provide courses on computer applications at graduate level, and both offer master's and doctoral degrees in this area. Improved facilities could be made available to teachers to take advantage of these programs.

However, any education in computer applications should have a substantial practical and empirical component. At the Provincial level, this translates into the setting up of specific CAI demonstration projects.

The present lack of hardware, courseware and, above all, personnel, leads to the conclusion that CAI can not and should not be introduced into all schools immediately. Moreover, if teachers are to be involved in its introduction and development, CAI should begin at centers of teacher interest and spread gradually as interest grows.

Such considerations lead to the proposal that CAI projects should be set up, initiated and operated by interested teachers with competence in CAI, to serve as demonstration projects. Necessary conditions would be support for such teachers, in the form of release time for program development, and professional recognition; and some assurance of continuity of the project over a period of years, in the form of both financial support and personnel. As in the PLATO project, it would also be necessary to provide co-ordination in order to avoid duplication of effort between projects and ensure a measure of compatibility; and to supply assistance from the already established centers of CAI in the Province.

It is considered that such projects could demonstrate to teachers the advantages to be derived from CAI, and lead to a gradual adoption of the technology. This occurred in an elementary school project in Calgary: it became obvious that use of the computer helped with marking, record keeping, the production of reports, giving help to slower learners and to students who had been absent, and providing enrichment to more able students. This resulted in the acceptance of the project by all teachers in the school (Brebner et al., 1980).

Teachers will accept and learn to use a technology that works, that helps them to do their job, that helps students to learn more effectively, and that allows more personal contact between the teacher and individual students.

The Organization of Learning and Instruction

The key to a better quality of education is the individualization of learning and instruction.

The industrialized societies of Western Europe and North America have organized their educational systems upon allegedly homogeneous classes of students under the charge of one teacher. The system was made possible by the second revolution in the storage and dissemination of information that was referred to earlier, namely, printing: it depends on the use of printed texts. Moreover, it has fulfilled its purpose, in ensuring universal education to a level needed by industrialized societies.

However, these very societies are now in the process of entering a technological era and are discovering the need for higher levels of education in their citizens. One consequence is pressure upon schools, and upon teachers, to ensure higher levels of achievement in their students. A solution is to provide opportunities for individualized learning. Most professionals in the field of education would now subscribe to the need for individualization, for open classrooms and a well structured curriculum.

It is questionable, however, whether such objectives can be adequately achieved without the introduction of a new dimension into the organization of learning and instruction. Studies in both Michigan and Oregon (Conant, 1973) have suggested that, with the present arrangements, a teacher is unable to devote more than one or two minutes per day of individual attention to each student. In the case of the latter study, this was despite the use of teacher aides. The problem with the present system is not that the teacher is not teaching; it is that, for lack of individual attention, students are not learning.

Attempts to apportion blame for this state of affairs are pointless. The present system has simply reached the limits of its capacity.

It is suggested that a new dimension can now be introduced by making use of the information storage, processing, and distributing capabilities of computers. The present study has indicated that, appropriately used, CAI can help ensure that students will receive a greater degree of individual attention than they receive at present, that they will learn more quickly and effectively, and that they will have a positive attitude towards future learning.

However, it must be acknowledged that the manner in which CAI has been introduced into ongoing instructional situations has varied considerably, depending upon the availability and type of hardware and courseware, the local definition of the term "individualization", and the necessity of articulating CAI with other forms of instruction. This is illustrated by a consideration of the CAI projects reviewed earlier.

In Germany, at both Garbsen and Augsburg, the CAI projects had available a room containing 30 terminals, or sufficient for a complete class of students. At Garbsen, students in a class using CAI pursued a segment of the course at their own pace for a period of two weeks, following which all started together on the next segment, using either CAI if courseware was available, or class instruction if it was not. In Augsburg, complete courses were implemented as CAI, particularly in mathematics and science, so that all students in a class proceeded at their individual rates throughout the course.

In the U.S., CCC has followed the procedure of making available approximately 16 terminals, or sufficient for half of one complete class. The assumption is that the teacher first gives the initial instruction on a new topic to one half of the class; these students then take drill and practice on the same topic at the computer terminal under the supervision of an aide. The second half of the class alternates with the first half.

Instruction by the teacher is therefore given in comparatively small classes, and students proceed at individual rates for drill and practice.

The PLATO schools project has sometimes used 16 terminals to provide for half of a class, but has always supplied tutorial material as well as drill and practice.

In all these cases, a management system has been used to route students through the sequence of CAI programs, giving remediation where appropriate.

However, the PLATO schools project has also made use of a teacher controlled management system. The teacher is provided with a list of all CAI programs available and, being familiar with the needs, strengths and weaknesses of students in the class, can use a simple system to prescribe a set of programs to be taken by any one student. When specifications for this individualized set of programs have been entered into the computer, the management system delivers the required topics. Such a system has been used by teachers having a small number of terminals, up to four in number, in a corner of the classroom.

Sometimes, as in Minneapolis, terminals have been located in a school resource center. Either the resource specialist or class teachers have then scheduled their use. In yet other cases two or more students have worked together at one terminal and when simulations are used this can be quite profitable.

It is obviously not necessary to provide a terminal for every student in a class. For the most part, there are too few CAI programs available to make effective use of so many terminals. But in any case, the assumption that a terminal is required for each student in a class, or school, appears to be related to a further assumption that instruction will continue to be provided on the same classroom basis as at the present time. The effective use of CAI to individualize instruction will likely require different forms of organization, and no rigid assumptions should be made which prevent appropriate development.

In practice, CAI has been and will be employed in many different ways in an attempt to individualize instruction. As already indicated, the lack of courseware, and the general organization of a school, impose limits on what may initially be achieved. In the beginning, all that can reasonably be expected is that a limited amount of individualized learning will be provided for some students in some subject areas.

In setting up demonstration projects, such practical limitations must necessarily be kept in mind. The important consideration is that there should be a potential for growth over time.

The changes in the forms of education that were facilitated by the invention of printing were not realized for several hundreds of years. Changes related to the present technological revolution will occur much more quickly. However, this revolution is only just beginning and the technology itself is in a process of rapid development.

Speculation may suggest a variety of scenarios including, for example, the disappearance of schools. The difficulty is that there is at present no substantive evidence to indicate that any particular speculation is relevant to reality. Certainly, there is not yet any evidence to suggest that schools are superfluous; rather, the evidence is all to the contrary.

It is possible, however, to point to directions in which it is both desirable and feasible to move during the next few years, and to propose means of encouraging and facilitating such movement. This is the intent of the present study.

Availability of CAI Courseware

If CAI is to be encouraged in the Province, as suggested, further questions are: for what students should it be provided and in what areas of the curriculum? Answers to these questions are needed before specific proposals can be made with regard to CAI demonstration projects.

A significant consideration is the present move away from mainframes, and even away from mini-computers, in favor of microcomputers as delivery systems for CAI. Associated with this is the probable use of BASIC, at least in the near future, as the most common CAI language. This and related language problems are discussed later.

A further consideration is that CAI is moving quickly away from text-bound courseware on hard copy or two-tone display type terminals. More recently developed programs use graphics, color, and multi-media terminals.

The implication is that it may be difficult to find courseware that can be readily used in the schools of the Province.

In the case of the major CAI projects which have been discussed, a considerable amount of proprietory courseware is available for the CCC, CDC PLATO, and TICCIT systems. However, although most of this is very effective, reasons have already been given why systems of this type should not be adopted in this Province at the present juncture. Other excellent courseware is available on the University of Illinois PLATO system, but is written in TUTOR, a language not generally available.

Several sources of reference list CAI programs which are available free, or for a nominal fee. The most comprehensive of these is the Index to Computer Based Learning, issued by the Instructional Media Laboratory of the University of Wisconsin-Milwaukee (Wang, 1978). Further references may be obtained through the Academic Computing Directory (1977). Curriculum materials in CAI form may be purchased from sources such as Digital Equipment Corporation, and CONDUIT. The latter is a non-profit organization established specifically for the distribution of quality courseware. However, it must be borne in mind that, althought Digital Equipment Corporation now offers a microcomputer, it is primarily concerned with mini-computers and its CAI courseware is similarly oriented. Further, any publication dated 1978 or earlier will amost inevitably have few references to courseware for microcomputers. An ERIC search yielded nothing of significance. CONDUIT has recently begun to distribute CAI courseware for microcomputers in BASIC. The first programs are biological simulations for the PET microcomputer and others, including some for the TRS-80 and APPLE II, are due to follow (e.g. Reiners et al, 1979).

The journals catering for microcomputer hobbyists carry numerous advertisements for software. These include very few CAI programs, however, and those that do exist are for short, unrelated units, mostly of dubious value. Small software firms are beginning to offer educational programs, which are generally text bound in order to cater to as wide a market as possible. In Ontario, Sheridan College has adapted some of the OISE college mathematics programs for the PET and is now distributing them on cassette tapes. As with most CAI programs commercially available for microcomputers, these have no record keeping system.

The general conclusion is that, at the present time, there are no programs available for microcomputers which both represent state of the art CAI and provide a substantial segment of a school course. The most that can be said is that isolated programs exist, and there are many examples of courseware from which ideas may be obtained for the development of microcomputer programs.

During the last year a number of alliances have been made between educational publishing firms and microcomputer manufacturers. Obviously, the objective is to produce educational packages, comprising hardware and CAI courseware. One publishing company has developed a series of mathematics programs, with record keeping facilities, which are available for the PET, TRS-80 and APPLE II, and distributes them on cassettes for $200 U.S. Such programs could prove useful, although it should be noted that they are related to American rather than Canadian curricula. Other publishing firms can be expected to produce similar programs during the next two years. However, for Canadian purposes, and to make full use of graphics and image projection, it may be assumed that substantial modifications will likely be required.

At the present time the CAI projects at the Universities of Alberta, Calgary and Lethbridge have very little courseware which is already available on microcomputers. At the University of Alberta, drill and practice programs in arithmetic have been written for the TRS-80. At the

University of Calgary, sets of multi-media programs to teach social survival skills to developmentally hadicapped persons have been in regular use for more than two years on an S-100 based microcomputer, and other programs are also available or under development; however, all are specific to this machine. Other programs for drill and practice exercises in written French are at present being developed for the COMPUCOLOR. The most important resource available in the Alberta projects at the present time is the experience gained with CAI on mini-computers, and the more recent experience with CAI on microcomputers. Such experience resides in the personnel of the projects.

The conclusion is that the decision to introduce microcomputers to develop CAI would help provide a better quality of education in the Province; however, this entails a further decision to develop most of the necessary courseware locally. Such courseware could be expected to be of interest to other parts of Canada.

Priorities in the Development of CAI Courseware

The need to develop courseware locally necessitates a strategy based upon priorities for CAI which takes into account both student needs and subject area content.

The continuing large scale CAI projects in the U.S. have for the most part been concerned with disadvantaged students, frequently ethnic minorities, who need help with mathematics, reading, and language at elementary and junior high school level. Such projects have been dependent upon federal funds provided specifically for low achieving and economically handicapped students.

In Alberta there are comparatively few such students, except in certain areas of the two large cities, and in small remote rural communities. However, some students are "disadvantaged" in that they have developmental handicaps, suffer from learning disabilities, have been absent from school due to illness, or live in rural areas where access to educational facilities is comparatively difficult. Many adults have had poor educational opportunites and have inadequate skills in basic subjects, so that they are unable to make their full potential contribution to the work force. For all such persons, it is necessary to have a high instructor/student ratio because of the variety of student problems and needs, giving a high cost per student hour; yet the amount of individual attention received by each student is still inadequate. It is in this kind of situation that CAI can be expected to be both effective and comparatively inexpensive.

The education of developmentally handicapped students provides an obvious case where CAI can justifiably be introduced at the present time. The retarded, physically handicapped, hearing impaired, or partially sighted, for example, all require education which involves a high ratio of instructors to students. In 1979, the cost of special education per student hour for the Calgary Board of Education was $5.56. It has already been indicated in the discussion of costs that, at this level, the add-on cost of CAI makes it a justifiable tool for the teacher. Present indications are that, both in the U.S. and the U.K., this has now been appreciated. In these countries, also in Australia and New Zealand, numerous projects to develop CAI with the handicapped have begun during the last two years. Experience with CAI for the developmentally handicapped in the University of Calgary project has shown over a period of nine years that it is effective. It has also demonstrated that, using courseware carefully developed to their specifications, teachers experienced in the use of CAI are able to devote more time to the individual difficulties of students (Hallworth and Brebner, 1980). Similar experience has been obtained with the hearing impaired in the U.S. (Watson, 1978), and with the physically handicapped in Germany (Augsburger and Lampl, 1980). As indicated earlier, courseware for the developmentally handicapped has been primarily concerned with social survival skills such as money handling, shopping, and simple reading. For persons with other types of handicaps a variety of curriculum areas have been covered depending upon student needs, but basic skills in mathematics and language have figured prominently.

There is little experience of CAI with students having learning disabilities. However, there is every reason to believe such students would also benefit from the greater degree of individual attention available when CAI is used, especially in the area of basic skills.

Students requiring remedial education following absence from school, or for any other reason, may need CAI programs relating to almost any part of the curriculum. This also applies to students in rural areas. In both cases, however, the most urgent need is in the basic skill areas of mathematics, reading, and language, and primarily at the lower levels.

Similarly, in adult education, the need is most urgent in the areas of mathematics, reading, and language. The teaching approaches needed for adults, and the types of examples, are different from those used with younger students. For adult students, therefore, different CAI programs are required. The success of the PLATO basic skills courseware, however, indicates the need for this type of CAI (Fahy, 1980).

For all disadvantaged students the benefits of working at a computer terminal are numerous. Many have already experienced frustration, defeat and frequently ridicule in their earlier educational experiences. They are motivated by CAI programs which give frequent and positive reinforcement; and older students in particular appreciate the opportunity to make mistakes and to learn from them without exposure to other students.

However, it must also be emphasized that CAI can help provide a better quality of education to all students. In mathematics, for example, the PLATO schools project has been particularly successful. Further, most teachers of mathematics readily accept computers as useful tools and are quite likely to initiate proposals for CAI projects. Such projects could be of special value, at any level, when they go beyond drill and practice. There is ample scope for the development of new and imaginative courseware, of the PLATO type, using the graphics and multi-media terminals now becoming available. Further, there is good reason to believe that such programs could raise the level of achievement in mathematics among all students.

The same considerations apply to the teaching of science. Simulations are particularly effective in these subject areas. Models are provided by the PLATO chemistry programs of Smith (1976), the physics programs of Bork (1979), and the biology programs from Chelsea College (Lewis, 1980). Multi-media terminals could be effective: they could provide audio instructions to a student engaged in manipulating an experiment on a color monitor; or show details of an experiment, too dangerous or expensive for the student to conduct in person, by means of a videodisc. At a more routine level, several programs have been written to teach topics requiring much drill and practice, such as stochiometry.

Vocational education could similarly benefit from CAI using multimedia terminals. Programs have been developed at the University of Calgary on the COMPUCOLOR, for example, to teach the operation of an internal combustion engine, and the use of a micrometer. Again, videodiscs would be particularly useful.

In the case of foreign languages, CAI can be used for drill and practice exercises in written work, and can save considerable teacher time and effort which may be used in teaching the oral language. This is already being done in the teaching of French (Kidd and Holmes, 1980). In the future, videodiscs will be introduced to teach oral languages.

For students such as those discussed above, and for the subject areas indicated, CAI would be particularly effective. However, to ensure acceptance and integration into ongoing instructional arrangements, it should be developed with the active participation of the teachers concerned. In the present climate of growing teacher interest, CAI projects can and should arise from teacher initiative.

With these considerations in mind, it is suggested that a number of CAI demonstration projects could be established. Preferably, these would be based upon proposals made by teachers in a school or school district, who would undertake operational responsibility for the projects, and receive adequate funding and release time. Whilst preference could be given to projects concerned with the students and subject areas discussed above, priority should go to proposals based upon active teacher interest, participation and competence.

Assistance would be needed from CAI specialists. Also, co-ordination would be required to ensure there was no overlapping of effort, to promote the sharing of courseware (Mason, 1980) and, hopefully, to encourage adequate documentation of courseware (Hunka, 1979). It would be important to ensure that copyright to any courseware developed with Provincial assistance was retained in the public domain.

A certain compatibility of equipment could be obtained by arranging bulk purchase contracts, on a Provincial basis, by means of which the schools and school districts could acquire hardware at a comparatively low cost. However, this would entail the setting up of acceptable specifications for equipment, also the guarantee of maintenance facilities at reasonable cost.

It is assumed that such projects would at the present time be based upon multi-user microcomputer sytems, located in a school or school district so that communications expenses would be kept to a minimum and local interest and control would be maximized. It is further assumed that, now or in the near future, considerable use would be made of graphics and multi-media terminals; also that co-ordination would facilitate a transition to the use of videodiscs within the next few years.

There remains the problem of computer languages, which is discussed in the following pages.

CAI Languages

The Problem

Until recently, the time and effort required to generate good courseware was only the second most important factor inhibiting the rapid growth of CAI; the first was the cost of buying and maintaining hardware. However, with the decrease in cost and increase in reliability of hardware, the cost of producing quality courseware has become the dominating factor. The economics of courseware development costs would be dramatically improved if courseware were easily exchangeable between different computer systems and educational institutions.

At present this is not a practical reality due to software considerations, specifically the profusion of CAI languages, dialects of languages, and time-sharing operating systems. Program portability is currently a major problem in many areas of computer applications, and has been a subject of research in computer science.

One method of overcoming the problem has been to design a common high level programming language. This approach has been reasonably successful in the area of numerical computations using FORTRAN IV as the standard for the practical exchange of programmed numerical algorithms. In business applications COBOL has served this purpose.

Attempts to produce a universal high level language to cover a large range of application areas have not been successful. The trend has been for special purpose languages to evolve in different problem areas. Hence, many special purpose languages for authoring courseware material for computer aided instruction have been developed at various CAI centers. Examples of these languages are COURSEWRITER, TUTOR, PLANIT, CAN, Leeds Authoring Language (LAL), and also NATAL-74 which has been developed by the National Research Council of Canada from these earlier languages.

Other centers have adapted languages that were already available in interactive form. For example, BASIC, APL and interactive versions of FORTRAN have been extended or adapted for CAI purposes.

To further complicate the situation some projects have opted for execution and memory usage efficiency by programming in machine code for one particular hardware configuration. For example, the early Stanford work, and more recently the Computer Curriculum Corporation's materials, used machine code. This approach has the advantage of running efficiently with minimal memory requirements and with relatively good response time. The director of the Los Nietos project claimed that having course material in machine code allowed him to run more terminals with good response time on a given hardware system.

Unfortunately, this approach also has major disadvantages. First, it is virtually impossible for anyone to modify the course material without consulting the original coders. Teachers quite rightly would object to being unable to modify course material with which the student was interacting without teacher intervention. The situation is very different from that of displaying film or TV, where every student is experiencing the same audio visual information and the teacher can make comments or criticisms to the whole class at the appropriate moment. In CAI students are progressing individually at their own rate.

Secondly, once the material is programmed in machine code it can only be run on one type of computer hardware.

Thirdly, the time required to write and develop course material in machine code can be very great indeed compared to the alternative of using suitable widely available high level languages.

Writing courseware in such a high level language has the advantage of making the lessons available on a variety of computers. Also the development time is considerably shorter than that needed to produce comparable courseware in machine code, and knowledgeable teachers would be able to modify some of the course material.

However, when essential features such as answer processing and student file handling have to be specially programmed in a high level language, this reduces the advantage over machine code for development time and ease of course modification.

The special CAI authoring languages have the advantage of automatically providing simple standard answer processing, and student file handling. For straightforward frame orientated CAI this speeds the development process and allows teachers to modify courseware with relative ease. However, some of these automatic features may inhibit the development of more powerful and effective CAI teaching strategies. Also these special languages tend to be available on only one or two types of machines. Further, if the language becomes too elaborate the computer space and time requirements become too large and consequently costs increase and response times deteriorate. This, however, can also be equally true for general-purpose high level languages.

As there is at present effective course material available in many different programming systems, an important question arises. How can these materials be easily made available on systems other than the original host system? The question raises two major problems relating to, first, the language used by the courseware author and, second, the type and complexity of the terminal equipment and associated materials, such as, slides, microfiche, video and audio tapes.

With regard to the first problem, a considerable amount of research has recently gone into the general question of portability of software. Of particular importance is the work of Brown, Waite and Poole in this area (Brown, 1975). Their approach is to standardize on a base language available on a range of computers, on to which CAI authoring languages would be mapped by a special translator system written in the base language and drawing heavily on the methods used in high level macroprocessors. The possible applications of these techniques are considered in a later section.

With regard to the second problem, audio-visual material cannot be automatically changed. For example, one system using microfiche cannot readily utilize courseware from another system using 35 mm slides for the visual presentation of pictures or complex graphics. Further incompatibilities include different raster sizes of display screens, and variations of codes for character sets. Only the setting of national and international standards will tend to alleviate these problems.

In the following sections there is a discussion of the factors influencing the design of a CAI authoring language, some high level and special languages currently in use for CAI, and the concept of a standard base language mentioned earlier.

The Design of CAI Authoring Languages

The first and most important factor in the design of a CAI authoring language relates to the needs of the human users. The language should efficiently allow an author to communicate appropriately with the student through the courseware which is developed. In other words, the author should be able to easily implement any one of a range of standard or new teaching strategies, and use a variety of forms of presentation of the material, without having to descend to awkward time consuming programming. Also, it should be possible for the courseware generated by the author to be easily adapted by individual teachers to suit local conditions, as teachers will not readily accept teaching packages over which they have no control. On the other hand, this must not lead to a language that is so simplistic that the author is faced with long and tedious programming tasks to perform even moderately complex CAI strategies. This implies a high level language which allows courseware to be fairly easily written, read and modified.

The operating system and ancilliary software can also facilitate or inhibit the author's efforts to produce effective courseware efficiently. Good editing and testing facilities are important in the initial developmental phase and later for the maintenance and improvement of courseware. During validation trials with students, and later to meet the needs of class teachers, the storing and analysis of data to measure course effectiveness and student performance are crucial if the courseware is to become educationally effective. Also the ability to easily build lessons, remedial routines, and tests into courses suitable for individual students or particular classes is important for both authors and teachers.

The form of hardware can also influence whether an effective and feasible authoring language can be developed for the available equipment. The role of terminals, particularly multi-media input/output devices, can be very important in determining the effectiveness of even the best courseware. As mentioned earlier, if a variety of terminals are used at different institutions, this can seriously impede the portability of courseware. The PLATO system wisely avoids this problem by a standard, but unfortunately costly, terminal. The hardware should also be able to handle economically the required number of users whilst maintaining an acceptable response time, whether a large multi-user system or a network of microcomputers is used. Although these factors are primarily influenced by the hardware and operating system, they are also influenced by, and can influence the form of the authoring language.

High Level Languages for CAI

A number of current general-purpose high level languages might be suitable for CAI.

FORTRAN IV is a widely used language, but has only weak non-standard character string handling capabilities. However, it is one of the two languages used by CONDUIT (the other is BASIC) for the exchange of courseware. The new standard FORTRAN 77 has reasonable character string handling, but has not yet been widely implemented. FORTRAN IV's strongest point is its almost universal availability.

PASCAL, or an extension of PASCAL such as ADA, the U.S. Department of Defence common language, might be considered in the future, but is not widely available in suitable interactive forms at present.

The two other obvious contenders are APL and the extended versions of BASIC which are now widely available. APL is a concise, powerful, interactive programming tool and cannot be ignored, but there are concerns that might be raised. First, run time efficiency may affect response time; second, suitable forms of APL have not generally been implemented on inexpensive hardware; and third, the author might find the language powerful but obscure, although this can to some extent be overcome by defining special functions and by using the macroprocessor base language ideas discussed later.

BASIC is a much simpler language and is implemented on a great variety of inexpensive hardware. Most present versions of BASIC have the necessary string handling capabilities and slightly better control statements than basic BASIC. The simplicity of this language is both a virtue and a handicap. It would be practicable to have authors or teachers write simple CAI material in BASIC, while a standard authoring system and other aids were being developed or improved. But the global nature and limited descriptiveness of variables in BASIC, and the inability to allow independent procedures, can prove to be an irritation to a person developing the author aids or large amounts of courseware.

For all its disadvantages, BASIC is widely available on relatively cheap hardware; it is possible to write macro facilities for the mapping of courseware on to BASIC; and there is the initial advantage that the teacher or inexperienced author can soon be taught to program in BASIC. Further, BASIC could be fairly easily used to teach students elementary programming.

The main contenders from available special purpose authoring languages are the following:

1. NATAL-74 was developed by the National Research Council and implemented on a PDP/10 in Ottawa. This language developed from the ideas of a committee representing interested persons from across Canada and also from experience with earlier CAI authoring languages such as CAN, COURSEWRITER, and TUTOR. A large part of the system is written in BCPL to aid portability to other computers. There are plans for a version which will allow development of the courseware on a large machine, but delivery of the course material to the students on small inexpensive microcomputers. Whether teachers could make local modifications to courseware in the latter approach is not clear yet.
2. TUTOR is the authoring language for the PLATO system described earlier. This requires a large, expensive CDC system for both development and delivery of courseware, but as already noted, a limited version is already available on a microcomputer. A large amount of courseware is available in TUTOR.

As both NATAL and TUTOR are authoring languages, modification of courseware would generally present no difficulties on the main operating system.

A Present Solution

The above considerations lead to the suggestion that a widely available interactive programming language should be used as a base language for CAI authoring. This should be supplemented by a general pre-processor, written in the base language and using macro facilities which can map high level specialized authoring languages onto the base language. This would allow the future adoption, as a new base language, a "better" language spanning a wider programming space, and would only require the re-writing of the pre-processor. There is, of course, a tacit assumption that all programs representable in the old base language could be represented in the new base language. Essentially, this approach has recently been adopted by several CAI groups.

For example, at the Research Councils' Computer Based Learning Project, at the University of Leeds, the higher level authoring languages GAL and GALTS are mapped on to the lower level Leeds Authoring Language LAL (Leeds University, 1979). The approach, however, differs from the above in that the pre-processors are not written in their base language LAL but utilize a separate macro-processor.

This idea has been more completely carried out in the language CAMIL which was implemented by McDonald Douglas Automation and Softec Inc. for the Air Force Human Resources Laboratory at Lowry Air Force Base, Colorado (Pflasterer, 1978). The CAMIL language has been designed specifically for CAI and CMI purposes, and is essentially a base language which can be easily extended to provide more elaborate CAI and CMI features. It has the efficiency advantage that the implementation is geared to a particular computer system. However, the language would have to be re-implemented for another type of computer, which in theory would not be necessary if a commonly available high level language had been used as the base language. The code generated when mapping on to a high level language tends to execute less efficiently, but on an interactive multi-access system or a stand-alone system this may be of no significance compared to the human response time. On the other hand, inefficiencies which produced computer response times of greater than one second could be seriously detrimental to teaching effectiveness.

The National Research Council is producing translators that map courseware in other authoring languages such as TUTOR into the intermediate language used for NATAL-74 development. In effect, the intermediate language would be a base language, but it is not yet known what language will be used for writing the translators.

Voyce and Olivier of the Ontario Institute for Studies in Education proposed a system of translators for various authoring languages (Voyce and Olivier, 1978). At the University of Alberta Kenway described a language, MAGIC (Kenway, 1978), which was stated to be suitable for writing interpretors for authoring languages. Hoover wrote a string processing language, ALEX (Hoover, 1976), with elaborate pattern matching facilities which could be used for translating between programming languages. In fact, translators for higher level extended versions of ALEX were written in the original lower level of ALEX.

It is unfortunate that, so far, no unified approach has yet emerged from the various attempts to aid the development and portability of CAI authoring languages and courseware. At the present time it is difficult to recommend a particular course of action in the Province.

Various options might be considered. There is the possibility of implementing a special purpose language, or of buying a computer system with a CAI language and operating system already available.

The former solution, which includes a considerable investment in manpower and time, might take between one and upwards of three years to make operational. Current experience with software development suggest the longer time.

The latter option has some attractions in that a fair amount of courseware may already be available. However, the initial capital costs would be very large, and probably the annual running cost would also be very high because the hardware used tends to be older generation machines. Also, some package systems, such as those developed by CCC, are fixed and cannot be modified by teachers.

Another possibility is to utilize a high level language which is currently available on a range of computers. There may be some courseware available but again local modification by teachers, though possible, may not be easy because such languages were not specifically designed for authoring lesson material. Also, it would be necessary for the high level language to be implemented in an interactive form. Further, to allow macro-processor techniques, in order to improve the software interface for the author, would require that the language have reasonable string handling capability. This would in any event be necessary for the analysis of student responses. Also, the language must have functions and procedures to allow interaction with the operating system. In particular, such features as being able to time a student's response, to interrupt the system in certain ways, and to handle files, would certainly have to be incorporated in these functions and procedures.

At the present time, despite its disadvantages, BASIC appears to be the only interactive language that is readily available on a range of inexpensive computers. However, as mentioned earlier, the progress of interactive versions of PASCAL and developments of NATAL-74 should be carefully monitored for possible consideration later.

If an extended version of BASIC is adopted as a base language for CAI care should be taken to develop courseware in a manner that will allow relatively easy translation to a new base language in the future. This suggests the possibility of writing courseware in some standard authoring form which is mapped on to BASIC.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This report has indicated that, for a variety of students and in many different subject areas, the use of CAI has led to improved achievement. It has also shown that learning by CAI usually requires less time than learning by other means. Further, students have a positive attitude towards this type of learning, frequently accompanied by increased motivation and attention span.

It is therefore concluded that, despite the fact that it must be considered an add-on cost, CAI may be regarded as providing a cost-benefit and as being potentially a very effective tool in the hands of a teacher.

However, when CAI is to be introduced into an on-going instructional setting, problems may arise which relate to the availability of the required courseware. Also, among teachers there is a lack of knowledge about computers in general and CAI in particular.

There are four specific components, each one of which is vital to the successful operation of computer assisted instruction. Further, they must be brought together and completely integrated in order to form a whole capable of improving and enhancing the quality of education. These four areas are hardware, software, courseware and personnel.

Hardware

It appears that there are few substantial problems in the area of hardware, and those that there are will, in many senses, solve themselves. The rate at which new developments are taking place provides on balance more advantages than disadvantages, although there are a few of the latter. The major point here is that new devices are constantly coming on to the market and that the costs of almost all hardware are rapidly decreasing. This has several implications.

First, there is neither need nor justification for using large mainframe computers to deliver CAI in the public schools. Mini-computers could possibly be useful for research and development purposes, and in large centers might be the most cost-effective type of system in the immediate future. The emphasis, however, should be on the use of microcomputers capable of supporting a number of terminals. Within the near future microcomputer systems are expected to be available for up to 16 users. Thereafter, it is most probable that the number of users will increase and costs will decrease.

The need for a multi-user system is dictated by the requirement for centralized record-keeping facilities in order to provide effective monitoring of student progress and adequate support to teachers in the form of reports. If compatible, small microcomputers could be used as terminals to such systems and also, if desired, provide CAI in a stand-alone capacity without centralized record keeping.

Secondly, a multi-media terminal incorporating a touch sensitive input device, image projection, audio capabilities, graphics, and possibly animation should be introduced as soon as feasible as a standard terminal on CAI delivery systems.

Thirdly, since it appears that, within two years, a videodisc player under the control of a microcomputer will provide a comprehensive yet inexpensive CAI delivery system, the development of videodisc technology should be carefully monitored, and experimental work should be initiated in order to obtain experience in the development of courseware for videodiscs. However, there is at present a considerable and potentially expensive task associated with the use of videodiscs, namely, the production of the premaster materials in such a form that the master videodisc and subsequent copies can be made.

The disadvantage seen in the hardware field is that the constant production of new hardware can lead to users too often changing their equipment, necessitating the direction of manpower to the task of re-implementing already exisiting courseware rather than to the development of new materials. While total avoidance of this is seen as impossible, much care should be taken to keep it to a minimum.

The following recommendations are therefore put forward for consideration by the Department of Education:

1. that the Department encourage and facilitate the use of multi-user microcomputer systems for CAI;
2. that the Department also encourage the purchase of small microcomputers by schools, to be used for computer literacy and small scale CAI applications;

3. that the Department discourage the proliferation of too wide a variety of hardware devices in use in the Province by negotiating bulk-buying contracts with the manufacturers of such equipment;
4. that the Department facilitate the constant monitoring of new hardware products and the assessment of their potential usefulness for CAI, including mini and microcomputers, videodiscs, and communications systems such as Telidon;
5. that the Department support limited experimental work in the use of videodiscs and investigate the possibility of providing facilities for the assembly of the pre-master materials for videodiscs.

Software

The software has been defined as consisting of two parts, the operating system and the computer languages in which the CAI courseware is written. With regard to the former, it appears there is little that can be done in the short term. As the hardware manufacturers produce new hardware, so also do the software houses develop appropriate software, although it should be noted that such developments are usually about two years behind the announcement of the hardware. Hence there is often a two year time lag before the full potential of new computer hardware can be fully explored for CAI purposes. However, while the development of complex operating systems should rest entirely with the experienced design teams supported by the hardware manufacturers and software houses, efforts could be made to persuade them to standardize the user interface with the operating system.

In regard to computer languages, there has been a profusion of these. It was indeed apt that, when published in 1969, the best known reference on this topic had as its cover an illustration of the Tower of Babel (Sammet, 1969). In spite of many suggestions for some standardization, the situation is not much better today, with many languages used for CAI applications and, in addition, many "dialects" of the same language. In view of this rather confused picture of languages and while hardware developments are taking place so rapidly, those languages should be used which are produced by the computer industry and which are widely available on a variety of computers appropriate for CAI. At the present time there is only one such language, namely BASIC. This conclusion is reached regardless of the known shortcomings of BASIC, and the fact that it does not contain in the most convenient form every feature needed for CAI.

However, developments taking place in the United States suggest that this decision should be re-assessed from time to time and that, particularly, the progress made with the implementation and applications of PASCAL and its derivatives such as ADA should be closely monitored. The continuing development of the National Research Council CAI language, NATAL-74, should be carefully followed, and consideration given to its use if this appears appropriate. Another language whose progress should be watched is APL.

There are many versions of the BASIC language and, while it is hoped that recommendation 3 relating to hardware will curtail their use to some extent, it is inevitable that several versions at several levels will be in use. It is therefore recommended that the Department of Education consider:

1. the establishment of a central facility to effect translation from one version of BASIC to another wherever possible;
2. the encouragement of adequate documentation of CAI programs produced locally.

A detailed study, within one of the universities, of the definition of a base language into which CAI programs could be translated might be of considerable long-term value.

Finally, the ultimate solution to the language problem and its associated transferability problems may be that hardware will become such a relatively insignificant factor in the cost of CAI that users will simply be able to buy the appropriate hardware and associated language as part of the courseware package.

Courseware

There are two pertinent facts in the courseware area which are of major importance. The first is the large amount of time needed to develop good courseware. While there are no differences of opinion on this, the exact amount of time considered necessary to produce a student hour of material does vary and it seems reasonable to take the PLATO project figure of approximately 30 hours as a good guideline.

The second factor is that when the present situation is carefully examined very little courseware is actually available with the exception of the drill and practice type of CAI in elementary level mathematics, reading, and language. Much of this courseware could not be readily brought into use in Alberta for two reasons. First, its content does not entirely match that of the curriculum used in the Province and further, it cannot easily be made to do so. Secondly, its mode of delivery is such that it would be unacceptable to teachers, and this cannot be changed.

This does not mean that good courseware does not exist. It does in isolated topics here and there. But on the whole there are not substantial pieces of curriculum which could be immediately implemented here: incompatibility of hardware and software and their rapid development are all factors working against this. Rather there are good programs from which ideas for the production of effective courseware can be drawn.

Further, there is virtually no courseware at all for use with the new multi-media hardware and few examples which take full advantage of graphics and animation.

If CAI is to be brought into effective and widespread use there are in the courseware area very many substantial and time-consuming tasks which can probably only be addressed on the necessary large scale if the Department of Education plays a part in several ways.

There is a need for a co-ordinated effort within the Province to build effective CAI curricula with many groups contributing and exchanging materials, but with no duplication of effort on any topic because of the exceptionally large number of work hours involved.

It is recommended that the Department of Education:

1. facilitate the development of courseware, by teams of teachers and other persons having experience in CAI, by appropriate financing including, for example, release time for teachers;

2. monitor such courseware development to ensure continuity of curricula and prevent duplication of effort;
3. set up a mechanism for disseminating information on developments;
4. set up a mechanism for facilitating exchange of courseware, both within and outside the Province;
5. retain all copyrights in the public domain.

Courseware is certainly an area of major concern requiring co-ordination, financing and much intensive hard work on the part of educators if progress in CAI is to be made. Teachers must play a major role in courseware development.

Personnel

This is seen as another area of major concern although entirely different in nature from that of courseware. The proposed solutions are also very different. While the proposals to alleviate the courseware problems are based on co-ordination and funding, those required in the personnel area relate to education and the providing of information.

There is at the present time still an unbelievable lack of knowledge of the new technology, and consequently strong resistance to its use. Old myths of electronic brains and superhuman robots persist, and computers are not seen as tools, but rather as intelligent machines which will take over teachers' jobs, and even carry out evaluation of teachers without their knowledge.

CAI will not succeed in any environment where it does not have the full understanding and backing of the teachers.

It is therefore suggested that several approaches should be taken to the problem. First, and most important, it is suggested that demonstration projects be set up by teachers who are already knowledgeable and enthusiastic about CAI, with financial help from the Department of Education, and in cooperation with established research centers for computer applications in education in the Province. In this way the benefits of CAI will be clearly demonstrable and teachers seeing such projects will want the same facilities in their own classrooms.

A second educational need relates to courses covering the areas of CAI, CMI, computer literacy, and other educational uses of the new technology. These are required at various levels. In depth courses are already offered at graduate level in both Calgary and Edmonton preparing teachers to take a major role in the required courseware development. Further courses are, however, urgently needed in the in-service program and at the undergraduate level in order that all teachers gain some knowledge of the topic, even if only at the computer literacy level. This should become a required part of the undergraduate program.

Courses on computing, such as those presently taught in Minnesota and Manitoba, are also urgently needed in the schools. Considering that the oil exploration industry and many other businesses in Alberta make extensive use of computers, and consequently the demand for professionals in the area is high, the provision of such courses is considered a matter of urgency. Further, in this affluent province many students now have a hobby computer in their homes. It seems essential that they are taught to make the best use of this powerful tool.

Ways in which it is recommended that the Department of Education should act are:

1. to provide financial backing for the setting up of demonstration projects in CAI;
2. to provide encouragement and high professional status for those teachers who have competence in CAI so that they will participate in projects and engage in development of courseware;
3. to provide the necessary publicity for the demonstration projects;
4. to require new teachers to have some knowledge of use of computers in education;
5. to introduce courses on computing into the school curriculum.

Priority Areas for CAI

Those students who will benefit most from CAI are those for whom the patience and repetitiveness of the computer are of great assistance in their learning, those who require individual attention, those who for some reason have failed to learn in the normal classroom environment, those who feel inadequate and inferior and do not seek help from a teacher for fear of displaying their ignorance, those who do not have ready access to schools, and those studying subjects in which the computational and information processing power of the computer enhance learning.

In more concrete terms, and in a tentative order of priority, these students can be identified as:

1. Handicapped students

CAI has proved to be a surprisingly successful way of educating the handicapped whenever it has been tried. Further, it is a cost-effective method as these are students whose education is otherwise expensive, with many of them requiring constant individual assistance. The group includes the developmentally handicapped, who are usually both retarded and have physical disabilities; the physically handicapped; and the hearing impaired, with whom slightly modified versions of programs produced for normal students have been used successfully.

2. Disadvantaged students

   Although there are few comparable situations in Alberta to those found in Chicago and other areas where CCC materials are in use, there can be identified, nevertheless, sections of urban areas where student achievement is below the norm. In the U.S., disadvantaged students to be offered CAI have usually been identified as students from low-income families who are substantially below their expected level in reading.

3. Students in rural areas

   There is a demand for a higher quality of education for students in remote farming communities. CAI could act as a supplement to the correspondence courses which many of these students now take.

4. Students in adult education courses

   These students are often self-conscious about their lack of knowledge as they try to upgrade their basic mathematical and English skills or take courses for retraining in other areas.

   A secondary group here are the immigrants for whom English is not their first language.

5. Students studying topics for which simulations are appropriate

   The topics here include most branches of high school science such as physics, chemistry and biology; junior high school and high school mathematics; and high school vocational courses such as automotives and electronics. Simulations associated with laboratory work can be both cost-effective and time-saving.

6. Students studying foreign languages

   CAI can be applicable to any foreign language but, in Alberta, languages which could be taught include French, Ukranian, German, and Chinese.

The identification of these groups does not mean that CAI is not an effective teaching method for the main body of students; it invariably is. These are merely the students who would gain most from such instruction.

Gifted students do not appear among these groups. However, although they would not at present benefit so much from CAI due to general lack of courseware, they would gain a great amount of knowledge from exposure to computers in other ways where they could explore their structure and investigate their full programming capabilities.

Proposed Demonstration Projects

Based on the specific groups of students identified as benefiting most from CAI, it is recommended that certain demonstration projects be set up, led by carefully screened teachers and with the already well established university centers acting in a close consultancy role. These would be as follows, again in a tentative order of priority:

1. Basic living skills and vocational skills for the handicapped
2. Remedial mathematics, reading, and language at elementary level
3. Remedial mathematics, reading, and language for adults
4. High school vocational courses such as electronics and automotives
5. High school science
6. High school mathematics
7. Junior high school mathematics
8. A high school foreign language

As several of these topics cover very wide areas of the curriculum, they could be broken down into a number of sections each concentrating on a more specific area. Some demonstration projects should be in rural areas.

In determining priorities, the importance of teacher interest should be borne in mind. Projects should be accorded preference which arise from the initiative of teachers able and willing to develop the necessary courseware.

These recommendations for specific demonstration projects are considered to be the focal point of this report. They address both the major problems, namely lack of courseware and teacher apprehension regarding CAI, while at the same time providing some CAI as soon as possible for those who would benefit from it most. Each project should be expected to continue for a period of at least five years and, hopefully, both become institutionalized in its original site and spread to other locations.

It is not considered an opportune time to attempt to introduce CAI in the schools on a larger scale than this. The educational climate of the Province is unfortunately not yet ready for it. It would be a costly mistake to try and would only impede the eventual acceptance of CAI. Computer assisted instruction must be given time to evolve, during which time courseware must be built up and irrational fears of computers overcome.

Revolutions often fail to deliver what they promise. This is invariably because too much is expected too soon for too little effort. By moving in the ways outlined and by creating more projects as the demand arises, it is hoped that the present technological revolution can be harnessed to provide better quality education in a cost-effective manner. The introduction of CAI should be an evolution rather than a revolution; when people are closely involved there are always too many casualties associated with the latter. Computers should naturally find their place in the educational system.

These conclusions and recommendations have been written with an acute awareness that at the present time documents on any aspects of computing can be almost out of date before they are completed. However, there appears at the present time to be no radically new hardware on the horizon which will dramatically effect CAI, and which has not been taken into consideration. It is therefore felt that these conclusions will remain accurate and the recommendations valid for some time to come. Nevertheless, the sooner action be taken on them, the sooner and more fully the students of Alberta will benefit from the fruits of the on-going technological revolution.

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APPENDIX A

Further Remarks on CAI Languages

The Concept of a Base Language Extended by Macro-facilities for CAI

It would be unwise to pretend that a universal solution to the complex interacting factors in courseware portability can be found with our present knowledge and understanding of software design. Practical solutions will therefore have to involve a blend of suitably selected techniques that are currently understood state of the art software methods, which produce a system that is also acceptable to authors and teachers. The question of acceptability may be as much a matter of author and teacher education as a technical computer matter.

The basic problem is to find an appropriate base language, which is readily available on computer hardware systems and is suitable for CAI. Translators will then be developed in the base language, using a form of macro-processor or extended macro-processor, which map courseware from various authoring languages on to this base language.

The base language may be a language which is currently available on a variety of suitable computers, or a specially designed language which can be relatively easily implemented on such computers. It should not only have the basic control structures and data types necessary for CAI, but should also allow the easy implementation of translators and macro-facilities. Hence, once the base language is implemented or available on another machine, the translators would also be automatically available.

With this form of flexible interface between an authoring language and the base language, it is also possible to allow an evolution of authoring languages by using new macros to extend an authoring language experimentally. This also implies the possibility of a spectrum of authoring languages, ranging from one which is very simple and would allow an author with little programming experience to easily develop simple course material and computer based tests, to one which would allow very elaborate learning strategies using new developments in, say, artificial intelligence.

It would be naive to imply there are no problems with this approach. First, the audio visual material could not be automatically changed, as mentioned previously. Secondly, many problems arise from this multi-layered software approach. These include error messages occurring while executing course materials, which might refer to the base language or operating system rather than the authoring language. These are most likely to occur during the testing of a course, but could be a serious problem during the presentation of course material to a student. The several layers of software could also make trivial tasks like logging into the computer, obtaining certain lessons, and building and testing courses complicated, or at best tedious. These problems arise to a lesser extent in all current software systems, but could be more serious with multi-layered software.

On the other hand given certain essential operating system facilities, the flexibility in such a system can also be used to tailor the operating environment for each class of user. A teacher producing simple course material on the system could be prompted for text, question, or answer at appropriate points in a particular learning strategy. Also, an author developing large and complex course material could use the macro facilities to help reduce the effort required for tedious clerical and repetitive tasks.

Of course, in the long run, it is hoped that an (almost) ideal software system which is widely available on economically cheap hardware will exist, but this is not a present practical reality. The concepts suggested above would allow some evolution of authoring languages, as well as the distribution of operational, tested, and educationally validated courseware.

Factors Influencing the Design of a CAI Language

Factors which influence the design of a CAI authoring language, may be summarized as follows:

I. Human

  1. Students
  2. Teacher
  3. Author

II. Computer Software

  1. Operating System
     i. File handling
     ii. Interactive features
     iii. System functions such as interrupt handling, timing clocks, I/O control, etc.

2. Programming languages available that are suitable for CAI
3. Ancilliary Software
    - i. Text editors and course builders
    - ii. Testing and debugging facilities for subsections of courseware
    - iii. Packages for analysis of performance data
        - a. to measure effectiveness of course materials and
        - b. to measure student performance both for individuals and classes

III. Computer Hardware.

1. Appropriateness of the hardware system for CAI multi-user environments. The term "system" could include a set of microcomputers each handling one or more users.
2. Types of terminals. These are, of course, the interface between the human students and the computer.

APPENDIX B

Visits Made in Connection with the Study

Latest Visits Made by Members of the Study Team to CAI Projects

PLATO, University of Illinois	May, 1978
Chicago Board of Education	May, 1978
Los Nietos School District	June, 1978
TICCIT, Brigham Young University	May, 1979
TIES and MECC, Minnesota	May, 1979
National Research Council	October, 1979
University of Manitoba	October, 1978
University of Alberta	August, 1979
Projects in United Kingdom	July, 1978

Latest Visits to Calgary by Representatives of Commercial Manufacturers of CAI Systems

Control Data Corporation PLATO	August, 1978
Computer Curriculum Corporation	September, 1978